AERO ENGINEERING

A COMPREHENSIVE WORK FOR THOSE ENGAGED IN THE PRODUCTION, ASSEMBLY, TESTING, MAINTENANCE, AND OVERHAUL OF AIRCRAFT

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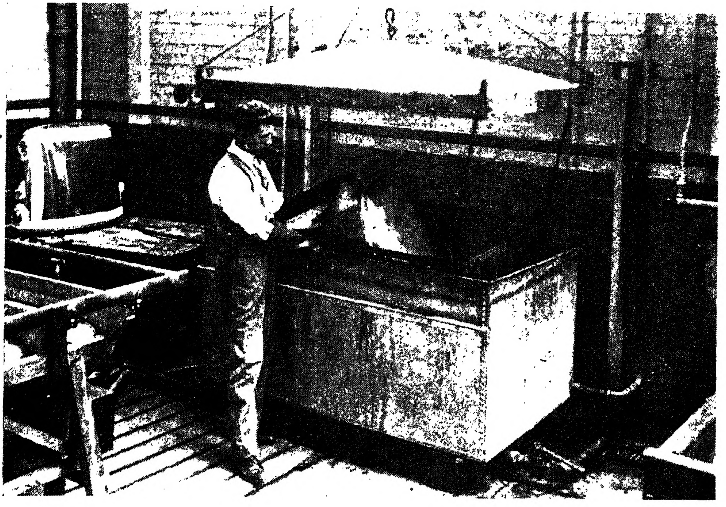


Fig. 14 (*above*).—CLEANING WELD IN BOILING TANK.

Fig. 15 (*right*).—HAMMERING THE WELD AFTER WASHING.

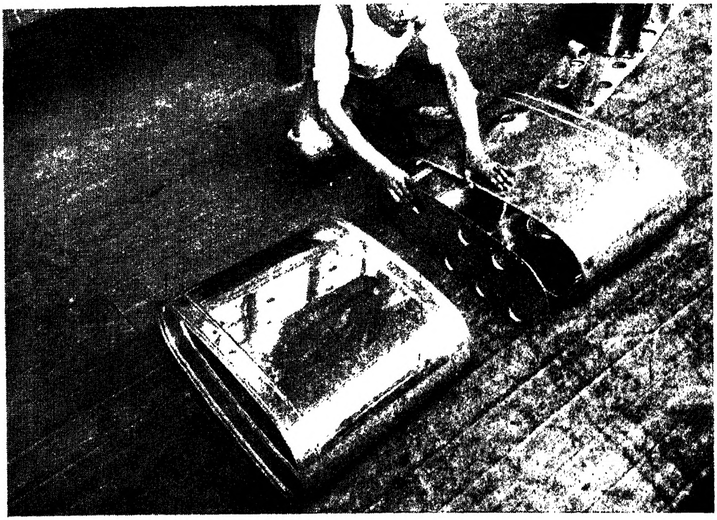


Fig. 16.—SHOWING BODY HALVES EDGED FOR ASSEMBLY TO BAFFLE.

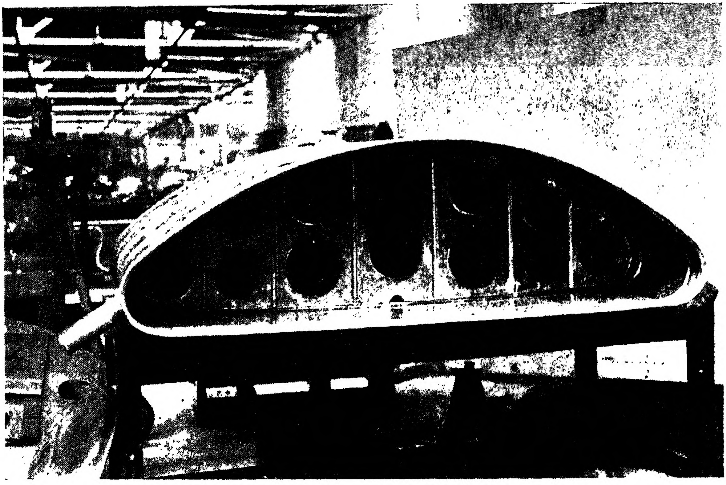


Fig. 17.—SHOWING AN ASSEMBLED BAFFLE.

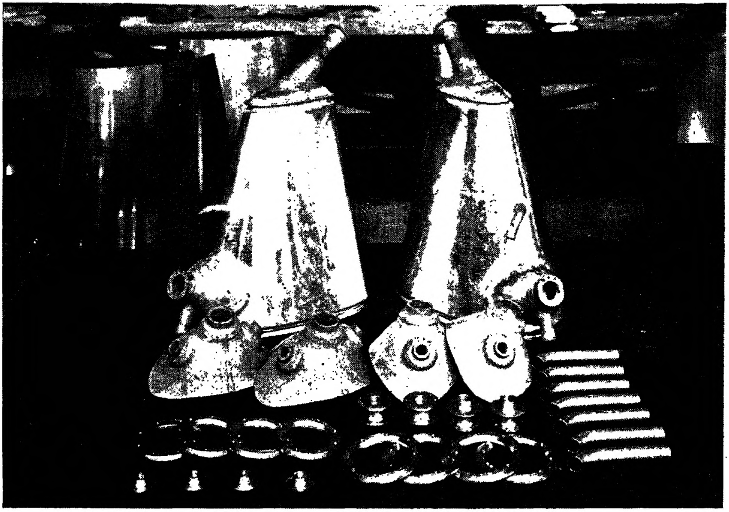


Fig. 18.—SHOWING FITTINGS AND ASSEMBLED SUMPS.

The welded portion is left in this for not less than twenty minutes, after which time all the flux has been dissolved and the weld is quite clean (Fig. 14).

The tank body is now ready to have the seam hammered flat—a process which tends to strengthen the weld and which corrects any slight distortion set up by the heat of welding (Fig. 15).

The tank body halves are edged for the purpose of attaching the ends and baffle plate. This is a similar operation to that of edging the end plates (Figs. 16 and 17).

Making the Sump

The sump is the next item. Although, in some limited cases, this can be formed in the body by beating and forming a depression, when the sump has to accommodate two or more fittings it is made up as a separate item. Regulations call for a drain sump in all tanks, the drain to be the lowest point of the tank when fitted in the aeroplane. Thus any moisture forming inside the tank, due to condensation, and any dust or foreign matter must be able to collect away from feed outlets. This is necessary whether the tanks are pump or gravity feed to the engines.

For most types of tank a drain plug is fitted in the sump at least 1 in. lower than the feed outlet, allowing ample space for the moisture to collect and be drained off at intervals. The outlet feed connection is

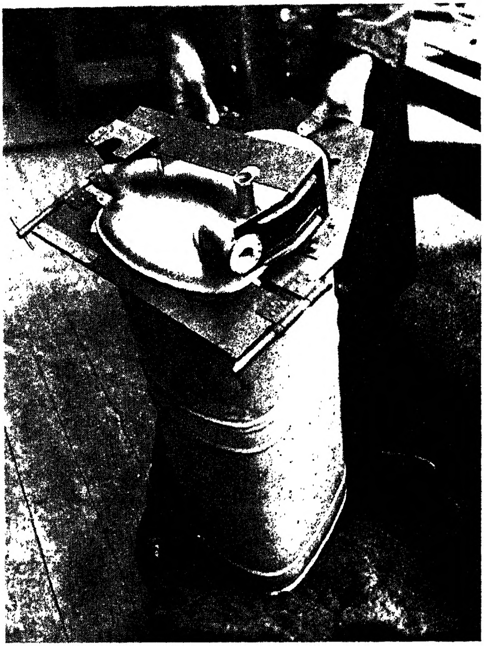


Fig. 19.—ASSEMBLY OF TANK IN JIG READY FOR TACKING WITH WELD.

fitted to the side of the sump, and holes are cut to suit the particular type of fitting, their position being marked from the pattern. These holes are then edged up and the fitting is placed on the turned-up edge.

The fittings are made of aluminium bar and designed to allow the portion to be welded to the same thickness material as the tank body ; if this is not so the difference in section will cause the fittings to crack when welding.

Assembling the Tank

With the completion of the sump the parts are ready for assembling. During the manufacture of the details (the end plates, baffles, tank body and sump) a centre line or datum has been set off on each part. This datum is the basis for assembly and must match up as each part is assembled, in order to keep the tank true. It also serves as a location and a check is kept on this during the welding operation to see that the tank does not distort (Fig. 19).

The two halves of the tank body are now checked up with the datum line, the baffle plate is inserted and all are cramped together with small vice cramps.

At this stage the dimensions are checked to ensure that they are working out correctly.

The parts are first tacked at intervals to keep the edges from opening out under the heat, and when they are tacked and set correctly the welding is commenced. After this welding the structure must again go through the cleaning and boiling operation to remove the flux.

The structure is now ready to have the sump and first end plate

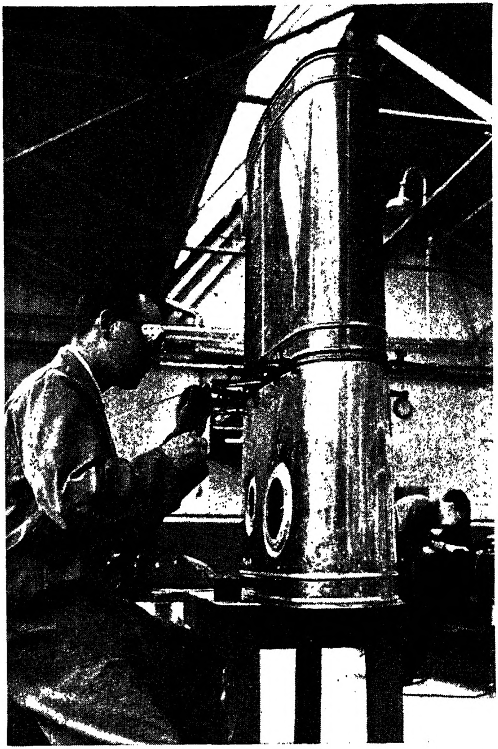


Fig. 20.—TACKING BODY HALVES AND BAFFLE WITH VICE CLAMPS IN POSITION.

fitted, and these are also set off to line up with the datum. They are then welded on, after which the cleaning operation is again carried out (Fig. 20).

The tank at this stage is complete, with the exception of one end, and it must now come under inspection supervision. With the drawings it is handed over to the Works Inspection Department, who check that all parts are correctly made and that the dimensions are accurate. A limit of not more than ·020 in. is normal for tank work; this must not be exceeded except by special concession from the designers.

When the Works Inspector is satisfied that all parts conform to the drawing the tank must be submitted for Aeronautical Inspection Directorate approval, on passing this check a record is made of the type of tank, the material used and the workman's name and number. This record must be filled in at every subsequent stage of inspection.

Anodic Treatment

The inspection is followed by anodic treatment to protect the tank from atmospheric corrosion, and the material both inside and outside the tank must be completely protected in this manner. Aluminium tanks cannot be anodised in one treatment, because the action of the bath during treatment evolves oxygen at the surface of the anode which rises to the highest point of the tank and causes bare patches. This means

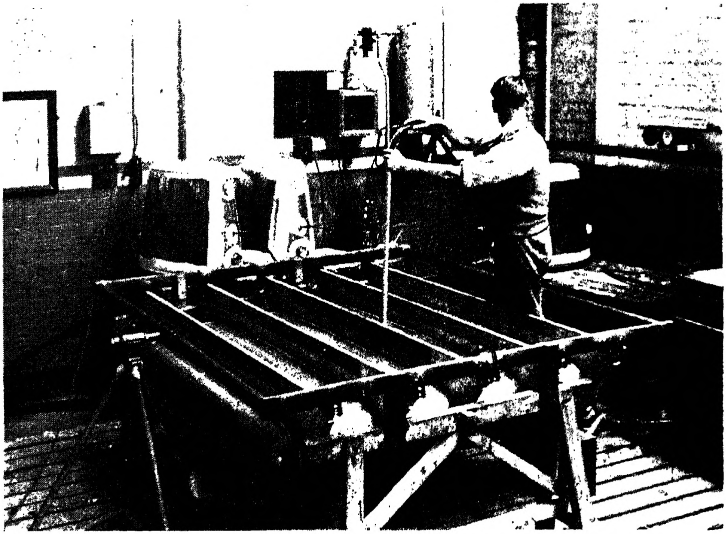


Fig. 21.—CAPACITY AND PRESSURE TESTS.

that the tank must be treated in two stages : (*a*) it is treated over three-quarters of its total length before the second end is welded on. After this treatment the tank is ready for final assembly and the welding on of the second end plate. Again after welding it must go through the cleaning off and boiling water treatment to remove the flux, and great care is taken to ensure that the anodised portion of the tank shall not be damaged. When assembled, it is anodised a second time to complete the operation.

The anodic treatment gives the surface of the material a very strong and adherent film of oxide and also helps to expose flaws. This treatment is compulsory on all tanks for service aeroplanes, but is optional for civil types. It is interesting to note that quite a number of tanks have been constructed without anodic treatment and have proved quite successful.

Testing a Type Tank

The tank is now ready for its tests, which are very severe for type tanks.

The first test is to check capacity, which must not be more or less than 2 per cent. of the amount called for on the drawings. The tank is rigged in exactly the same way as it would be mounted in the aeroplane. This is done by making a framework and strapping the tank in it, care

being taken that this framework and the securing arrangements are not stronger than those which will be used for securing the tank in the aeroplane (Fig. 22).

When rigged the tank is filled to capacity with paraffin, which is carefully checked out from it in gallons and its total capacity is recorded on a chart. For oil tanks this capacity test must allow for a stated air space, this must be taken into account when the total capacity is calculated.

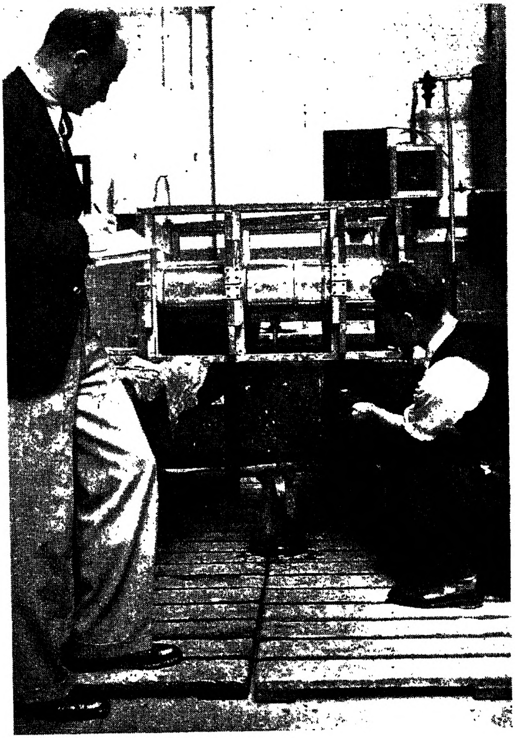


Fig. 22.—CAPACITY TEST.

After passing the capacity test the tank is put through a pressure test. The calculated pressure for fuel tanks is determined by formula to cover stresses set up in flight and must have a stated safety factor. This pressure is only applied to type tanks. Subsequent tanks need only a nominal pressure test of $1\frac{1}{2}$ lbs. per square inch. The tank should be supported during pressure test and is left in the supporting jig used for capacity test.

Paraffin is then poured in the tank to the equivalent of 10 per cent. total capacity and the tank is sealed, a coating of whitening is applied at all joints and welds and a pressure gauge to register pounds per square inch is fitted (Fig. 21).

Air is then pumped into the tank and very careful watch is kept for any signs of distortion. This work is carried out by the Inspectors, who keep a careful note of the pressure at which distortion, if any, takes place.

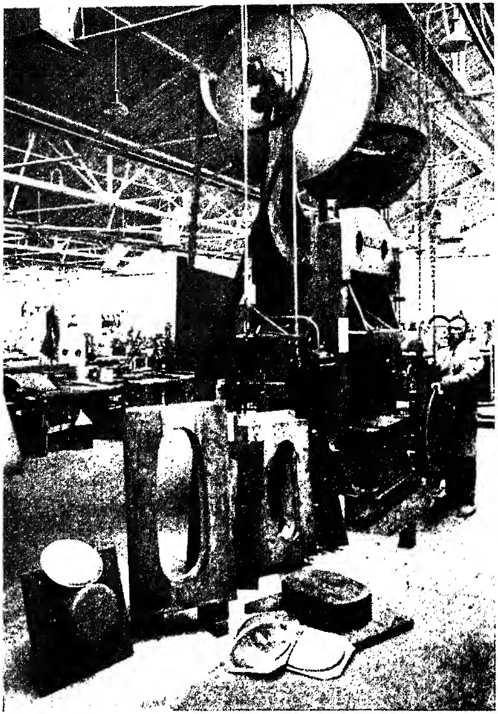


Fig. 23.—PRESS TOOLS FOR END PLATES.

This pressure must be maintained for twenty minutes, at the end of that period the tank must be turned about to allow the paraffin to reach all the parts. It is then inspected for leaks, which show a dark stain on the whitening.

It is a very rare occurrence for leaks to appear and this is evidence of the care taken during welding operations.

When the tank has stood under pressure without leaks appearing or distortion taking place it has passed its type test and is ready for final treatment in the form of cleaning: washing internally and externally in boiling water and drying in an oven at not more than 212° F.

The Static Test

This test is in some cases used instead of the air-pressure test in respect of tanks with a high loading figure, as it is not so rapid in attaining the necessary pressure. The tank is rigged in the testing jig in exactly the same manner as for the air pressure test. A flexible tube is attached to the highest orifice in the tank—usually the filling faucet. A board calibrated in feet and inches is rigged at the side of the tank for the purpose of determining the feet head necessary to raise the pressure in it to the required figure. It is then filled to capacity with water or petrol, and the flexible tube is allowed to fill slowly until the required head of pressure has been reached.

This method can be checked by fitting a mercury tube to the bottom

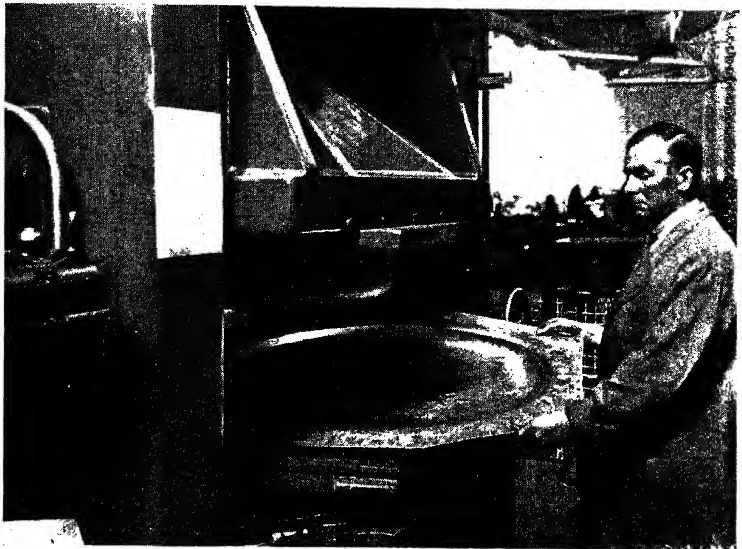


Fig. 24.—THE END PLATES FORMED.

Fig. 25.—MARKING OFF JIG FOR END PLATES.

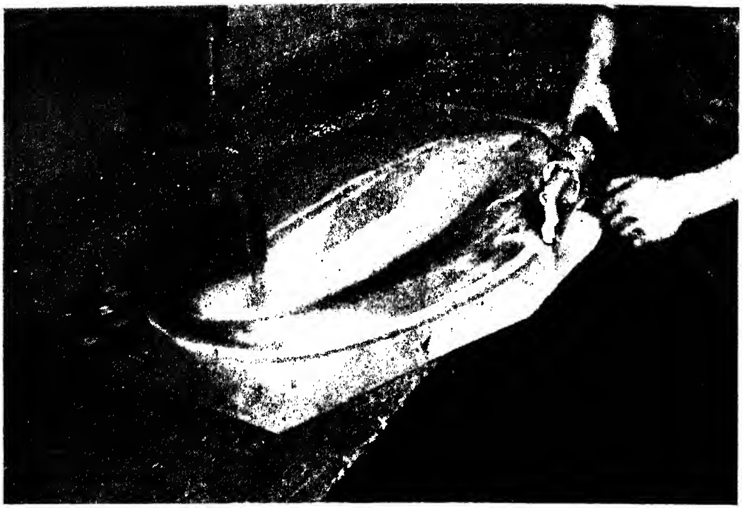


Fig. 26.—Trimming end plates.

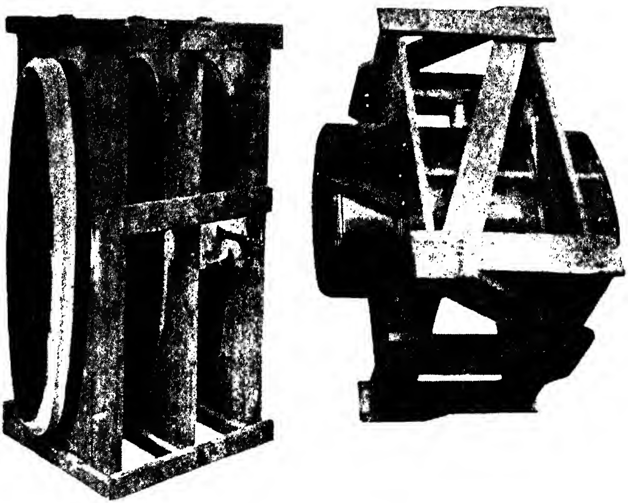


Fig. 27.—Showing pressure test jig.

of the tank and taking the pressure reading in lbs. per square inch.

The flexible tube is used for this test to enable the head to be dropped immediately any distortion takes place in the tank, thus avoiding the danger of bursting.

Allowance must be made for the fact that the liquids used for testing have a different specific gravity; 2·3 ft. of water is equivalent to 1 lb. per square inch, whereas petrol requires 3 ft. to equal the same pressure.

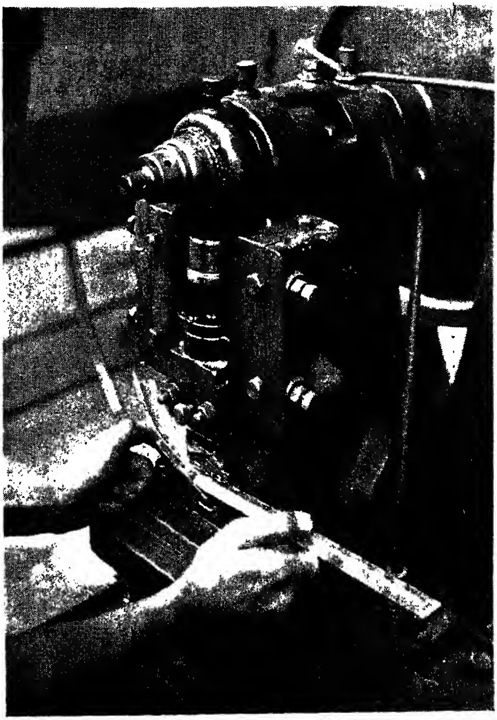


Fig. 28.—TACKING TOOL AND PRESS.

Mass Production of Tanks

This completion and final passing of the type tank now allows the engineers to set out for production and when the approximate quantities that will be required are given, a start may be made on jigging.

The importance of interchangeability of parts calls for great care. Jigs must be made, to ensure that every part is standardised, and in the case of fuel and oil tanks to make certain that the capacity is maintained. This is the responsibility of the jig and tool designers, who work out from the tank drawing the most suitable forms of jigs.

The first tool must be for shaping the end plates and consists of press tools made from wood. The wood does not mark the aluminium during forming, so that this method has been found to be most successful. The punch is made from beech blocks and shaped to suit the end plate. A die is then made, but the aperture is left open and is not shaped to correspond with the punch (Fig. 23).

A steel plate with rubber blocks placed on top is used for holding the

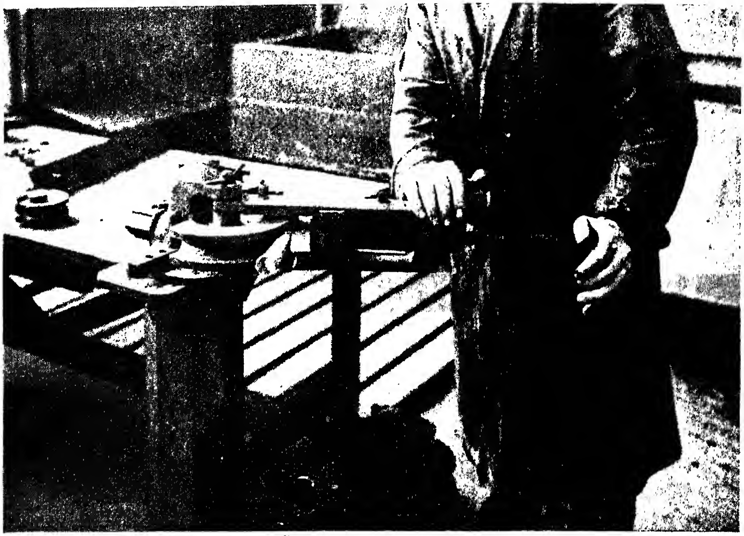


Fig. 29.—SMALL PIPE BENDING MACHINE

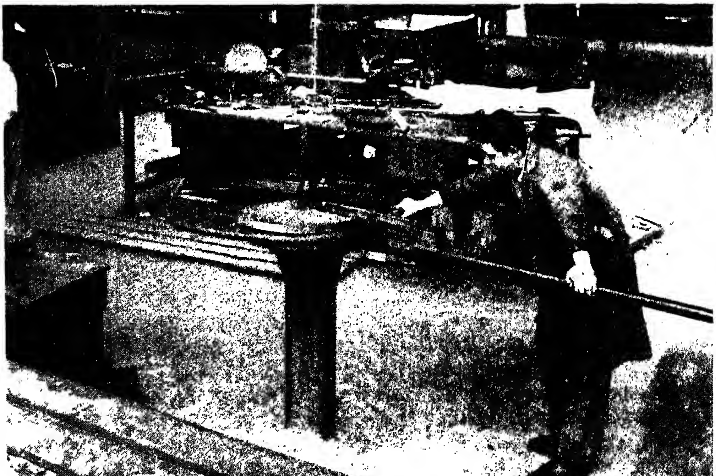


Fig. 30.—LARGE PIPE BENDING MACHINE.

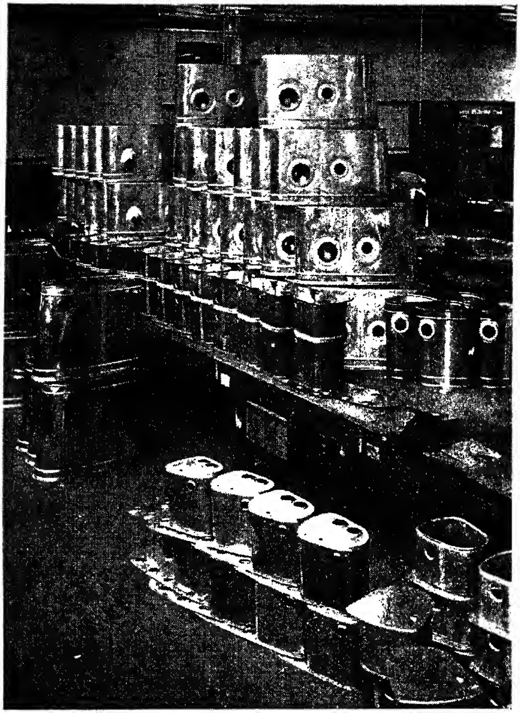


Fig. 31.—SHOWING VARIOUS PART FINISHED ASSEMBLIES.

aluminium in the die. This restricts the metal from flowing too quickly under pressure and results in a smooth and clean pressing (Fig. 24).

When ends are pressed in this way a certain amount of aluminium is left all round the edges, this must be cleaned off. A jig for marking-off the centre line of the end for location on assembly, consisting of a frame-work which fits over the contour of the end is used (Fig. 25).

The tank ends are now trimmed by means of power shears. This operation could be carried out much quicker if press tools, which consist of a shearing punch and die, were used, but for small quantities the tooling costs would be too high as against the marking-off method (Fig. 26).

The welding fixture—a structure built up from steel strips to suit the contour of the tank ends and body—is next in order of operation. This jig has locating pins and sockets for all fittings that require to be welded into the tank. It is not always possible to weld completely a tank while in the jig, so the parts are tacked together and welded when they are out of it. However, location being the most important point, this method is quite satisfactory (Fig. 19).

Welding jigs are also made for assembling the detail parts, such as sump and fittings, filler faucet and air-vent fittings.

An assembly jig, to embody every part of the tank that has to be checked for assembly (the inspection of details having, of course, already taken place), must be provided. This box-type jig should be very strong,

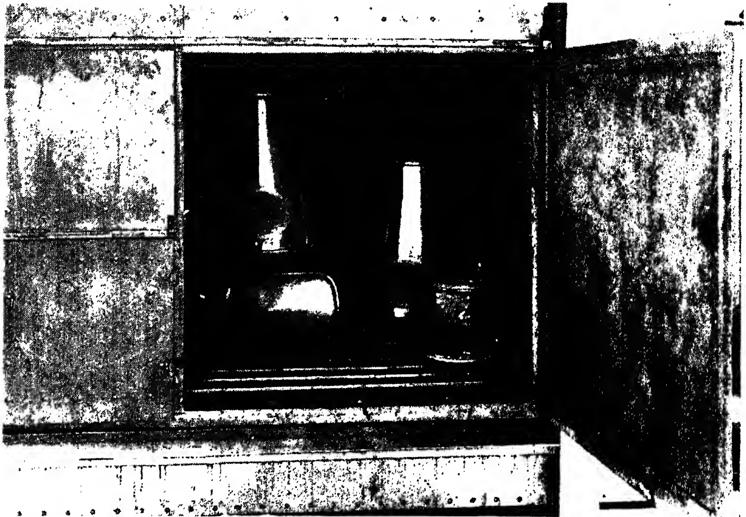


Fig. 32.—FINISHED TANKS IN DRYING OVEN.

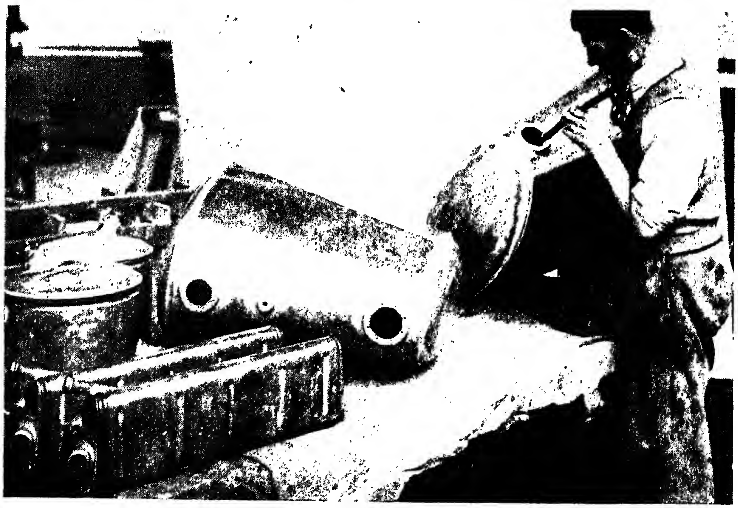


Fig. 33.—INTERNAL INSPECTION OF FINISHED TANKS.

so that it will not warp or twist, so wood and steel bracings are used in its making. It locates centres of ends and body and the positions of the various fittings, and it checks the external dimensions of the tank, including position of the body swages.

In some cases the assembly jig can be used for the pressure test, but this is not always practical because the wood tends to absorb paraffin. It is safer therefore to have separate jigs for mounting the tanks for the pressure test (Fig. 27).

Many small tools can be made during the manufacturing stages of aluminium tanks. The process operations will show instances where a tool can be used to advantage in order to save stressing the material. One such tool is known as the tucking tool.

This tool is for tucking the edges of the material and can be fitted in a small press. In operation it draws the metal together evenly, without marking. This enables angles and channels to be bent at varying radii without the usual hammering and bending operations (Fig. 28).

Bending of Tank Pipes

When pipes are bent over a certain diameter by hand operators it is necessary to load them with resin. The resin is first heated until it becomes fluid, after which it is poured into the pipe and allowed to cool; the pipe is then bent between wooden blocks. Constant checking, too, is necessary to ensure that the resin has not allowed the pipe to collapse. When the pipe has been bent to its correct shape the resin is removed by heat. Cleaning the inside of the pipe to free it from any obstructions is absolutely essential, this is done by immersion in cleaning solutions.

For bending and shaping the fuel and oil tank feed pipes without the necessity of filling them, a pipe-bending machine is used. The pipes are bent accurately by means of set-ups fitted to the machine, and is accomplished by means of a roller type of die shaped to the diameter of the pipe required to be bent. The pipe is placed in this roller and a former, of similar shape to the roller, is placed on the back of it. A lever arm is then adjusted to suit the radius of bend required, the lever is pulled round the former, which forces the pipe round the roller die, when bent the pipe is ready for assembling with the necessary fittings and welding-in to the tank (Figs. 29 and 30).

The shapes and sizes of welded aluminium tanks vary considerably to suit different aeroplanes, but the general principles apply in all cases.

MANUFACTURING ROUTINE

MAIN PLANE DETAILS

THE details, apart from the spars, which go to complete the structure of a stressed skin monoplane wing, consist chiefly of ribs of various designs dependent upon their particular function, stringers running parallel to the spars, fairing strips for the aileron and flaps and a trailing edge completing the upper skin for the span covered by the flaps. The wing tips may be detachable to facilitate assembly and replacement.

Centre Plane

For the centre plane, the leading edge, or that portion of the structure forward of the front spar, is made detachable to provide access to the numerous controls and mechanism between the fuselage cockpit and engine nacelle.

Outer Planes

In the case of the outer planes the leading edge is fixed and is integral with the skin covering. Access doors are provided at various points, such as control system junctions, electrical terminal stations, etc. Hinges for the ailerons and flaps are carried on ribs.

Ribs

The ribs, which form the skeleton structure in the fore and aft direction, *i.e.*, at right angles to the spar, are generally made up of three portions :—

(*a*) Nose rib forward of the front spar.
(*b*) Centre rib spaced between the spars.
(*c*) Tail rib fixed aft of the spars.

It will be seen from Fig. 1, which illustrates a diaphragm rib, that the

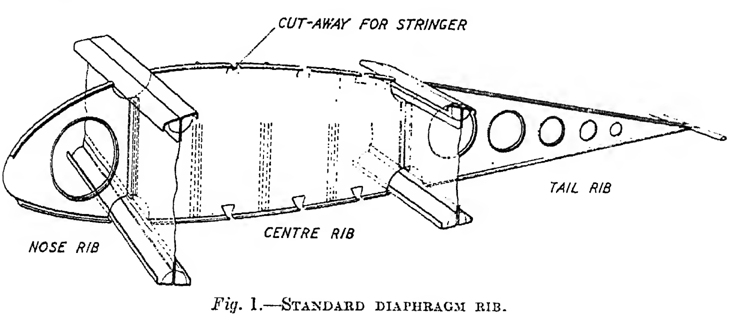


Fig. 1.—STANDARD DIAPHRAGM RIB.

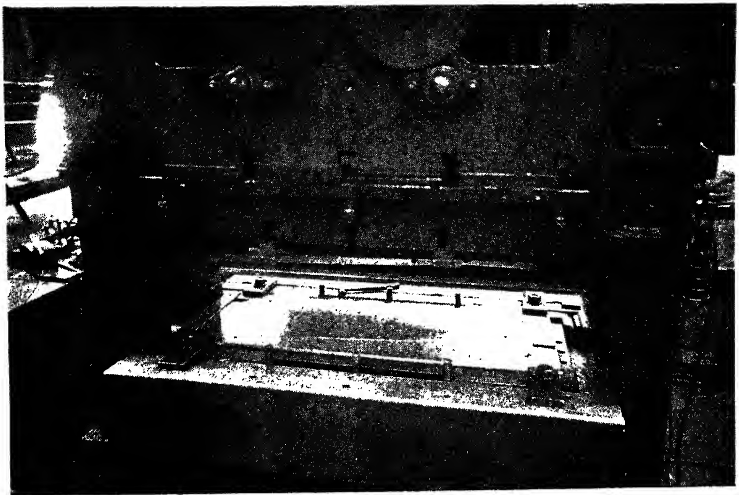


Fig. 1A.—RIB MANUFACTURE (1).
Showing tools mounted in press.

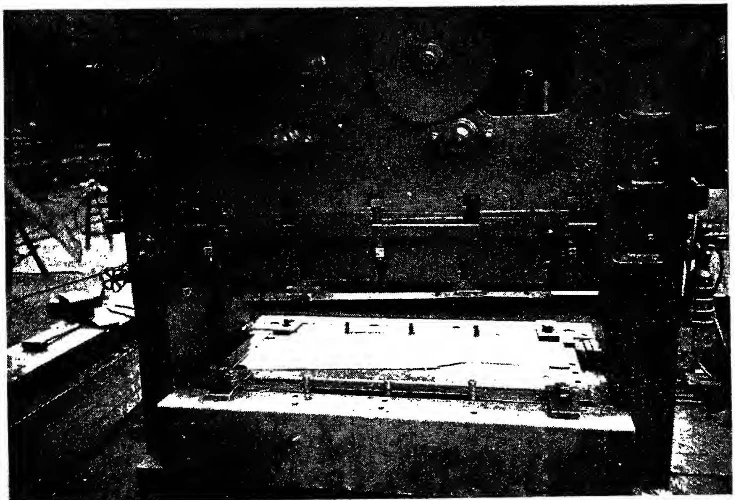
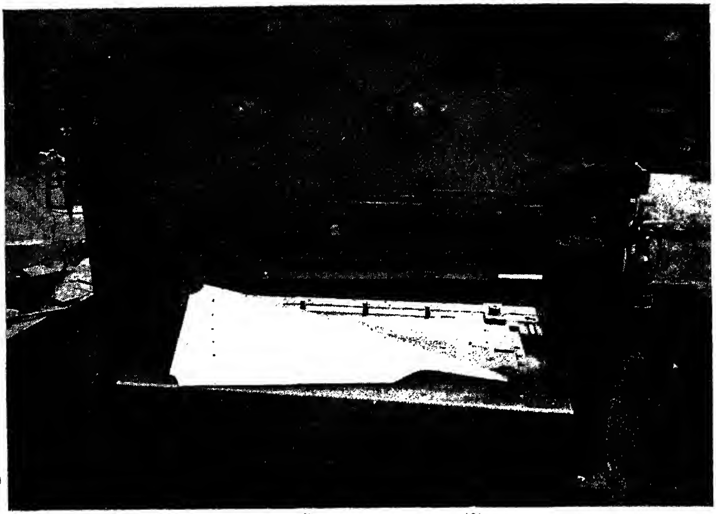


Fig. 1B.—RIB MANUFACTURE (2).
Showing blank in tools.



ig. 1C.—RIB MANUFACTURE (3).
Flanging up the two edges.

Fig. 1D.—RIB MANUFACTURE (4).
Turning over return flange.

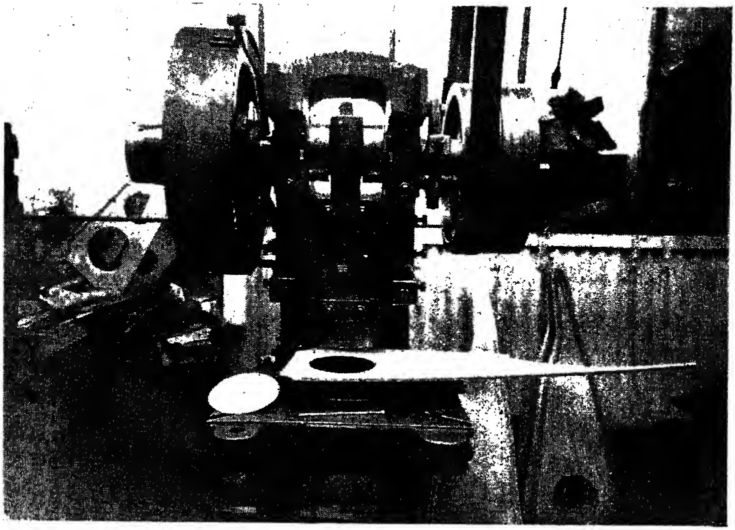


Fig. 1E.—RIB MANUFACTURE (5).
Blanking lightening holes.

nose rib contour is struck from comparatively small radii, whereas the shape of the centre and tail ribs depart only slightly from straight lines. This point is important when pressing the details as it is possible to fabricate the centre and tail ribs without heat treatment of the light alloy material, but in the case of the nose portion the standard salt bath normalising is necessary.

Operations for Rib Manufacture

The operations for rib manufacture consist of the following :—

(*a*) Mark off from template and drill pilot holes for centre of lightening holes and all other holes for rib fixing, etc.

(*b*) Cut blanks by using electrical hand shears.

(*c*) Punch holes for lightening.

(*d*) Raise flanges on contour and lightening holes by power press.

(*e*) Complete flanges by hand and notch for stringer gaps.

Press tool operations detailed on Figs. 1A–1G are an alternative to the above.

Jig Drilling of Spar Rib Angle Attachment

(*a*) In order to reduce assembly times for ribs it is necessary to carry

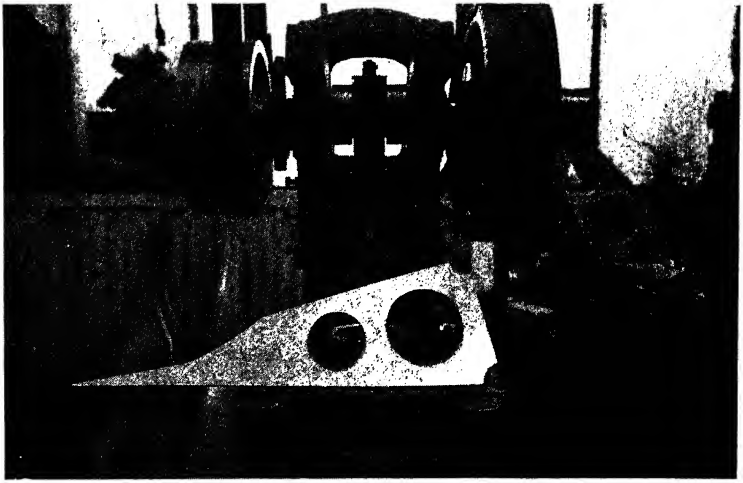


Fig. 1F.—Rib manufacture (6).
Lightening holes flanged up.

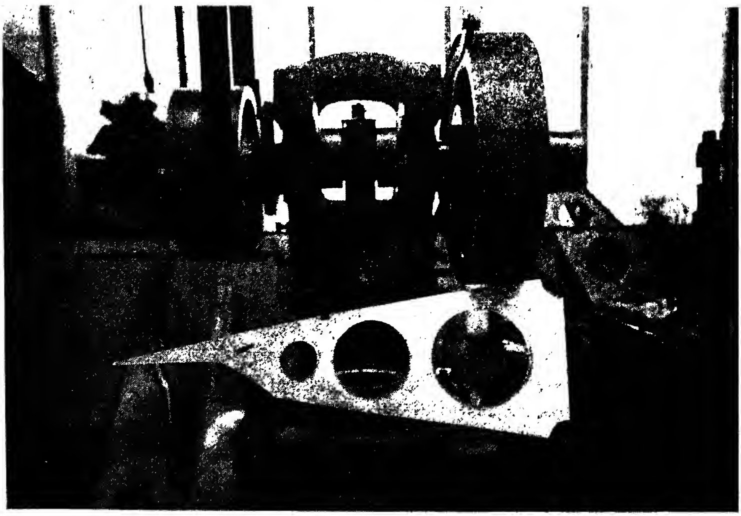


Fig. 1G.—Rib manufacture (7).
Showing bracket slot and stringer slot cut out.

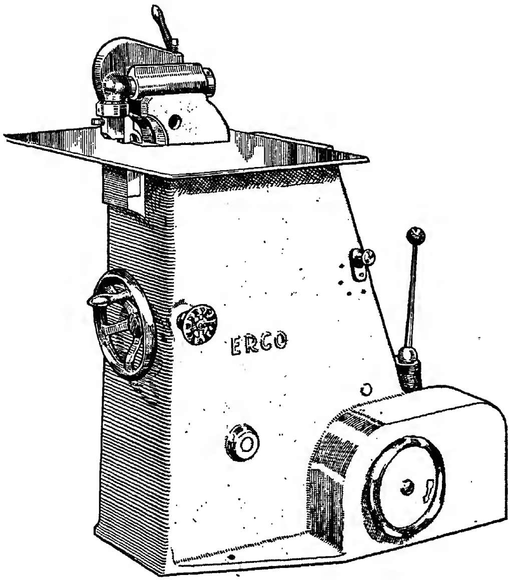


Fig. 2. — FLANGING AND FORMING MACHINE.
[" *Erco.*" *A. Wickham Ltd.*

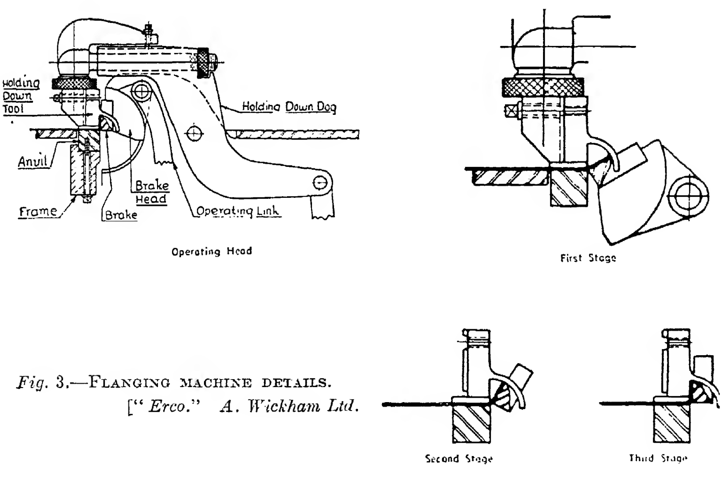


Fig. 3.—FLANGING MACHINE DETAILS.
[" *Erco.*" *A. Wickham Ltd.*

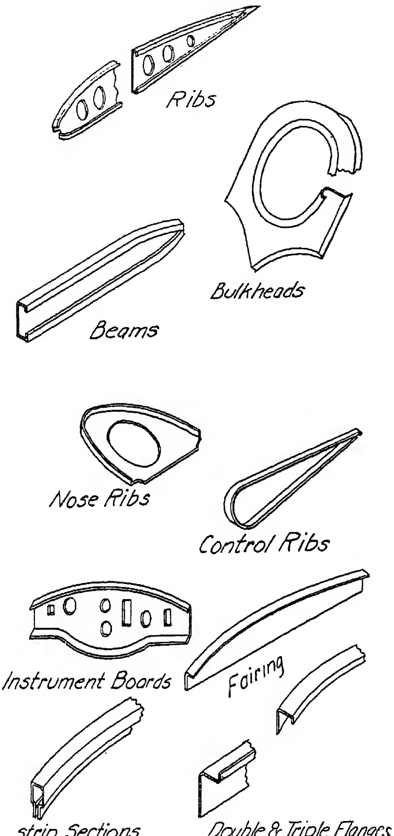


Fig. 4.—AIRFRAME DETAILS FORMED ON FLANGING MACHINE.

[" *Erco.*" *A. Wickham Ltd.*

out carefully the jig drilling of spar rib angle attachments and ribs, so that there is no drilling whatsoever on assembly, and with the ribs offered up in position and secured the spars remain in their correct relative positions.

From the foregoing it is evident that the drilled holes in rib for attachment to spars must form the basic location on press tools for carrying out the later operations in order to form the flange so that it truly lines up with the spar on assembly.

Alternative Methods

For the particular type of rib described above there are alternative methods for carrying out operations (*b*), (*d*) and (*e*).

Cutting Out Blanks

(*b*) The blanks can be cut out, using nibbling shears (Fig. 5). This method is particularly suitable for the heavier gauges in light alloy and also where steel plate is used. It is claimed for the nibbling shears that they will cut shapes from anywhere in the sheet without pre-punching and trimming can be carried out readily down to a very small radius. In addition to the above, straight or curved ribbing or beading can be done by the use of special tools.

Flanging and Forming

(*d*) and (*e*) Flanging and forming can be done by using a special machine designed for the purpose and illustrated in Figs. 2, 3, 4. This

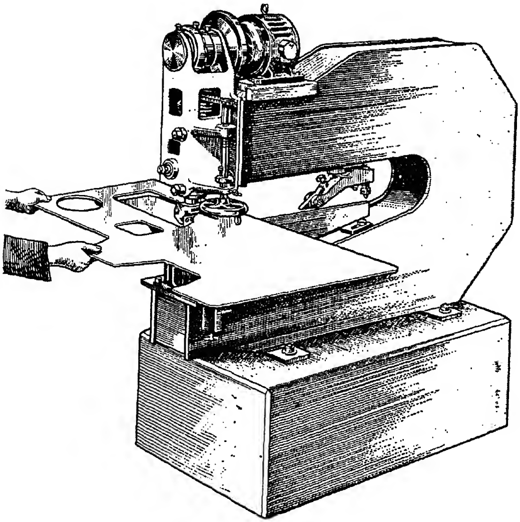


Fig. 5.—NIBBLING SHEARS AND PUNCH.
[*Henry Pels & Co. Ltd.*

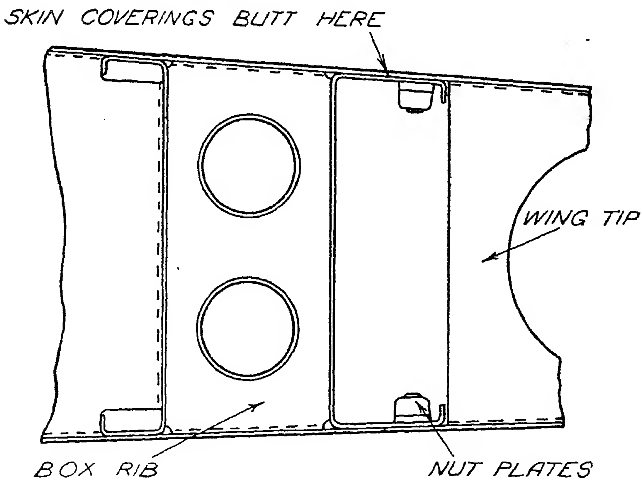


Fig. 6.—WING TIP ATTACHMENT.

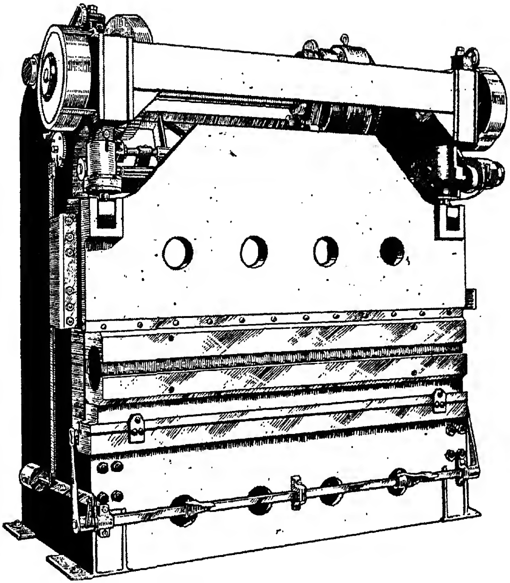


Fig. 7.—Folding press (open ended).
[*Henry Pels & Co. Ltd.*

machine is used to a great extent for turning over the flange at its outer edge after the flange has been raised at right angles. Details to be dealt with on this particular machine must be carefully selected, as for the simple shapes hand forming over steel plates often gives a better rate of output.

Tapered Tail Plane Spar

One very good application to be noted, although outside the main plane group, is the case of the tapered tail plane spar made from light alloy strip, which is flanged readily and makes a very satisfactory job. When carrying out the complete flanging of a rib with this machine two sets of tools are required. The first operation sets the flange up at right angles and the final one turns the edge over.

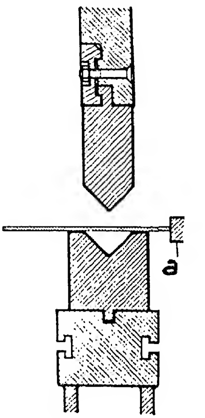


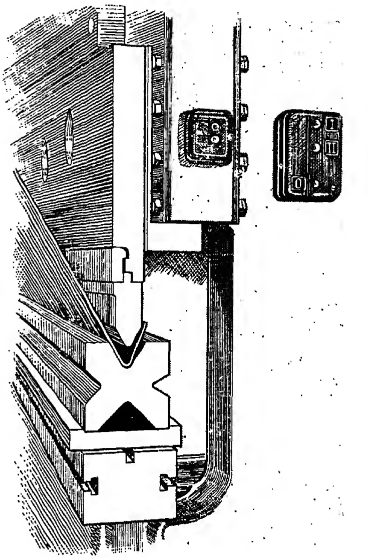
Fig. 8.—Tools for angle section.
[*Henry Pels & Co. Ltd.*

The Flanging Machine

For general information concerning the flanging machine, the following points may be noted :—

The machine will form straight, flared, half-round, offset, beaded and reverse flanges on straight, curved or irregular-shaped flat or crowned sheet metal. The machine will flange outside edges of circular discs, also inside edges when radius of inside circle is not less than 5 in. Forms wired or false wired edges on straight or

curved inside and outside edges. Forms inside and outside flanges on round or irregular-shaped cylinders where diameter is not less than 8 in. The range of oscillations is from 160 to 540 strokes per minute.



9.—LOWER TOOL WITH FOUR-TYPE GROOVES.

[*Henry Pels & Co. Ltd.*

Light Former Rib

In addition to the standard ribs made from sheet as described above, it may be that between each main rib a light former rib is introduced into the design to keep the free area of skin covering within the specified limits. This rib consists of two drawn or rolled sections of channel shape assembled with the webs vertical and lining up with the top and bottom contours of the aerofoil section. This particular form of rib would be used for the main area between the spars. Standard nose and tail ribs would be fitted to complete the group.

The manufacture of the former rib consists of rolling the section to contour, notching for stringers and drilling to jig for end attachments. The drilling of both the standard and former rib flanges for picking up the skin covering rivets is carried out on assembly.

Stringers

The stringer sections may be identical in form and material to those used for the fuselage construction previously described. The stringers having been cut to length are drilled for the skin covering rivets and end pick-up points and are then ready for assembly.

Wing Tips

There is a choice of two alternative methods for wing tip junction to the main portion of the wing :—

(*a*) The attachment can be made wholly by the skin covering fixings to the main wing.

(*b*) The wing tip structure members can be secured on to the spar ends in addition to the skin covering fixings.

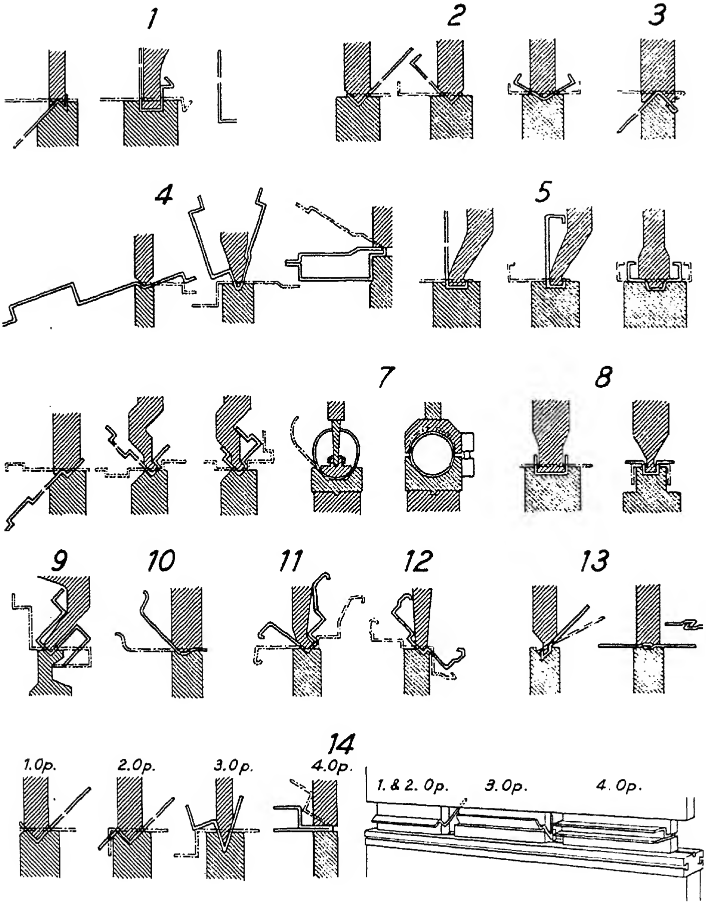


Fig. 10.—SECTIONS MADE ON FOLDING PRESS.

[*Henry Pels & Co. Ltd.*

(*a*) is now general practice; (*b*) introduces complications in providing access for the bolting at the spar ends. The general scheme is outlined in Fig. 6, and it will be seen that the outer end rib of the main portion wing is designed to give a seating for the wing tip skin

covering and also carries nut plates for securing the wing tip covering to the rib.

The details of the wing tip structure are simple ribs and formers made in the manner described for the standard ribs. The outer tip edge can be of metal or wooden construction, secured in place by rivets or screws.

Fairing Strips in Way of Flaps and Ailerons

These strips, fitted to complete the structure forward of the leading edge of the aileron and also on the upper surface of the planes in way of the flaps, are made from sections of channel or other forms which have a comparatively large profile.

Various methods can be employed to produce these sections, including drawing and pressing. It is found that when this class of section is drawn in long lengths and cut up there is a tendency to open out at the ends due to initial strain in the section. Pressing the section overcomes the trouble of end distortion and is a very efficient method to adopt when the quantities are sufficiently large to justify tool cost.

Folding Press

Particulars of one type of folding press suitable for this class of work are given in Figs. 7, 8, 9 and 10, and it will be noted that a big range of shapes can be produced. The sections having been formed into shape, the details are completed by jig drilling, notching, etc., as required.

Brackets, Inspection Doors and Small Details

All these details are manufactured by pressing from sheet, drilling from special plates and riveting up by hand or power machines. The spars, ribs and covering are jig drilled to accept these details, so that no special assembly jigs are necessary to attain correct positioning.

Skin Covering

The sheets, of Alclad or Dural, are with few exceptions "laid on" and require no forming into shape. Standard templates are used for marking off the sheets and the trimming to shape is carried out by electric hand shears. These templates can be used for drilling shrouds as the sheets are fully drilled at this stage.

For the leading edges the sheets are wrapped on a former, the drilling shroud placed over the sheet, clamped in position and the sheets are then drilled and marked off for trimming. The leading edge near the wing tip may require forming to produce the correct shape. This forming will be carried out in the power press.

Should difficulty be experienced in producing the requisite shapes in high strength light alloy thin sheets, it may be found that an aluminium alloy of about 12 tons/sq. in. tensile requiring no heat treatment for the forming operation will be the best choice of material for this part.

ENGINE INSTALLATIONS AND SERVICES

By R. H. Longe, *Inspector, Saunders-Roe, Ltd.*

THE inspection of engine installations and their services can be divided into two main categories—*i.e.*, during initial erection and, later, in service.

The following deals chiefly with the former.

In the case of the single-engined light aeroplane, the installation is comparatively simple, whilst the multi-engined aeroplane with its engines installed in mountings attached to the front spars of the upper or lower main planes, is rather more complicated.

Before dealing with the installation itself, we will consider the engine mounting or mountings.

Single-Engined Light Aeroplane

In the single-engined aeroplane, the mounting will be either of ash or it may be a welded tubular structure built up of a low carbon steel tube such as T.45. The thrust line will be a continuation of the centre line of the fuselage and its incidence will be parallel to the fuselage datum. A fireproof bulkhead is interposed between the engine and the fuselage and takes the form of a sandwich of asbestos sheet with a sheet of aluminium on either side.

Twin-Engined Aeroplanes

In the case of twin-engined aeroplanes, the engines may be carried either in the lower or the upper main planes, in between the two or in the case of a monoplane, carried on a mounting attached to both front and rear spars, the nacelle itself standing clear of the plane. In each of these cases the main anchorages are on the spars themselves.

Mountings

The mountings in this type of aeroplane are usually of tubular steel, either built up of tubes having fork-ends inserted at either end to enable the various members to be bolted together or else the structure is welded throughout with two rear stays having adjustable fork-ends, the latter allowing for alignment and adjustments when setting up the mountings on the main planes.

With regard to the incidence of this class of mounting, this may be nil or 2 to 3 degrees positive.

Their thrust lines may be parallel to the centre of the aeroplane or

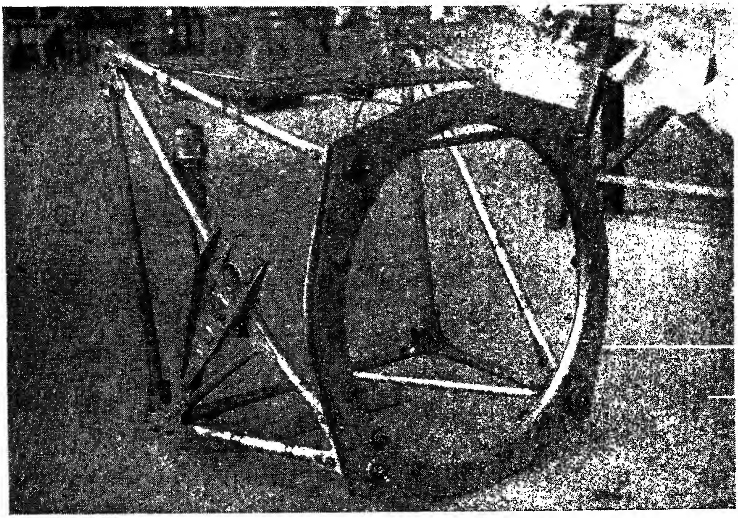


Fig. 1.—THE BUILT-UP TYPE OF ENGINE MOUNTING.

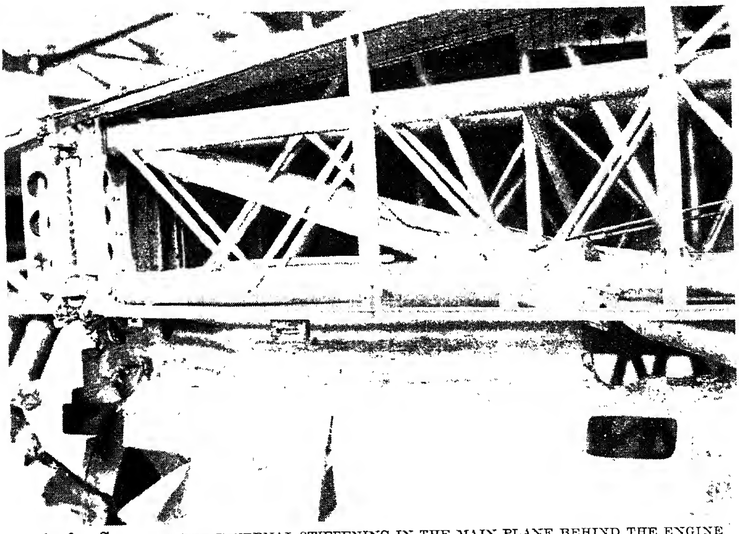


Fig. 2.—SHOWING THE INTERNAL STIFFENING IN THE MAIN PLANE BEHIND THE ENGINE MOUNTING.

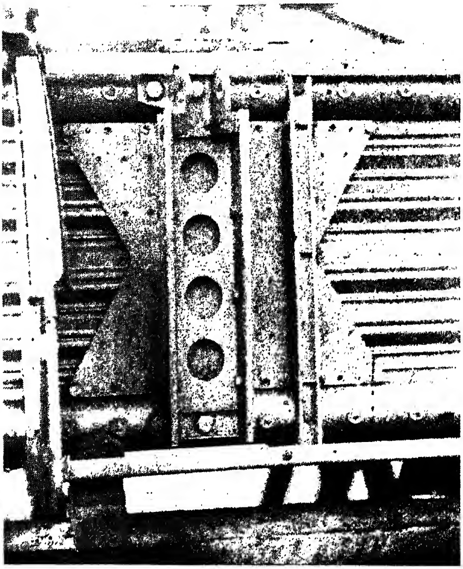


Fig. 3.—THE POINT OF ATTACHMENT TO THE FRONT SPAR FACE.

they may be off-set inboard—that is, the slipstream from the two nacelles may converge towards the tail. This is largely governed by the design of the tail unit to give the most effective tail control. A tolerance of plus or minus 15′ is usually allowed when aligning the mountings.

Before installing the engine in a single-engined aeroplane, the bearers or mountings should be checked by setting the fuselage up level fore and aft and also laterally. A straightedge placed across the bearers will enable a clino to be used to check them for lateral level. If rubber mountings are employed, the straightedge should sit in the bearer brackets which house the former. The incidence will be checked by means of a clino on the bearers themselves or else by means of a straightedge sitting on front and rear brackets on either bearer.

A check should also be made for square by measuring back to a point on the main plane on either side, equidistant from the centre line of the fuselage.

If the mounting is to carry a static radial engine, incidence and thrust line will be checked, lateral level not being applicable in this case.

All attachment bolts should be checked for having no thread in shear, washers being fitted, if necessary, to ensure this.

The mountings on a twin-engined installation can be checked by taking dimensions from the bearers or bearer plates back to the spar face.

Care must be taken to ensure that the lugs on the engine mountings are a snug fit in the attachment lugs at the spar face. If necessary, steel shims are fitted to obtain this.

Most engine mountings of the tubular steel type carry a serial number plate and an inspection stamp; they are sweated on in a prominent position.

Static radial engines are carried on the front or bearer ring either

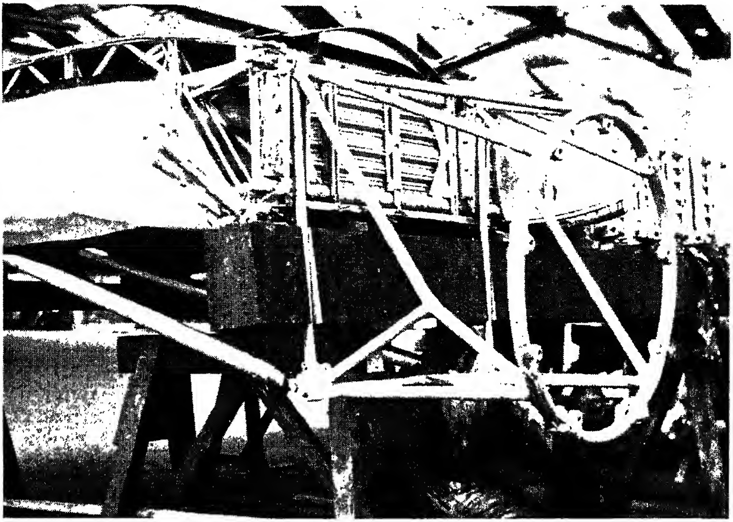


Fig. 4.—THE WELDED TYPE OF ENGINE MOUNTING BEING OFFERED UP TO THE MAIN PLANE.

through a dished steel pressing or through Lord type shock-absorbing units. In the case of the former, the steel pressing is attached permanently to the engine crankcase by means of a series of studs ; in the latter, the Lord units are assembled on the engine before installation.

Stationary in-line engines are sometimes bolted rigidly to the wooden or tubular steel bearers, but it is becoming general practice to provide brackets, housing rubber blocks, in which the four engine feet are accommodated. Care must be taken to provide sufficient clearance around the feet to allow for movement of the engine when slow running.

Methods of Lifting Engines

All engines are provided with means of lifting. In some cases a spreader is necessary to hold the sling clear and prevent the load from being taken on push-rod housings and rocker gear covers. The engine should not be lifted until ready to install in the aeroplane as it is bad practice to leave the engine suspended for an indefinite period.

The carburetter and air intake on some types of radial engines have to be removed before attachment of the engine to its mounting, although provision is sometimes made to remove a segment of the engine bearer ring to allow the carburetter to pass through. The segment is then replaced. Should the carburetter be removed, care must be taken when replacing it to obtain a gas-tight joint between the carburetter and the

gas case. The smaller engines may employ a Hallite washer, but the larger types have a face joint, when a thin layer of gold size or other jointing compound may be used. The minimum amount should be used, however, as it must not be allowed to run down inside the carburetter choke housings.

Fig. 5.—CHECKING THE INCIDENCE OF THE MOUNTING.

ENGINE SERVICES

After installing the engine or engines in the airframe, the various services to provide its correct functioning and efficient control will have to be installed. These can be classified under the following headings :—

Fuel system.
Oil system.
Throttle and mixture controls
Fuel cock controls.
Cooling system.
Exhaust system.
Ignition.
Starters.
Cowling and Townend rings.
Airscrews.

Auxiliary services such as air intake shutters, slow-running cut-outs, etc.

For the purpose of this article, a twin-engined aeroplane, with engines installed in the upper main planes, will be taken as an example.

The Fuel System

The duty of this system is to supply an adequate and continuous supply of fuel to both engines at all altitudes or attitudes of the aero-

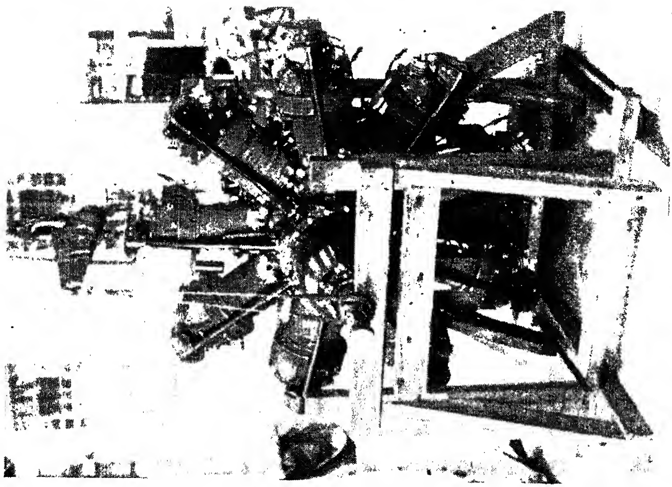


Fig. 6.—CARE MUST BE TAKEN WHEN SLINGING THE ENGINE.

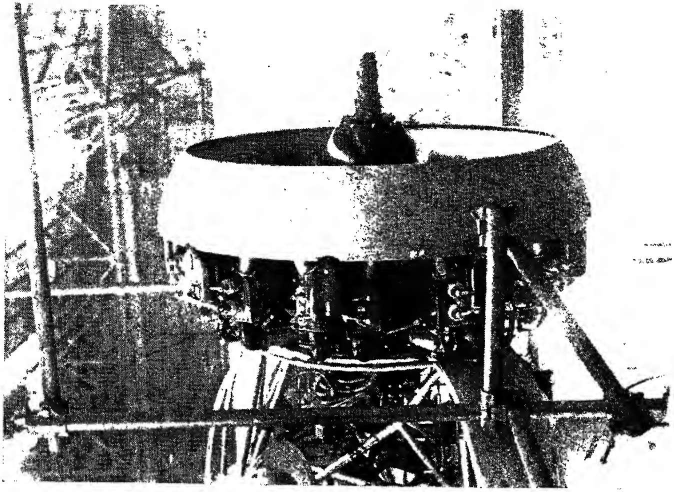


Fig. 7.—THE ENGINE INSTALLED AND THE EXHAUST RING FITTED.

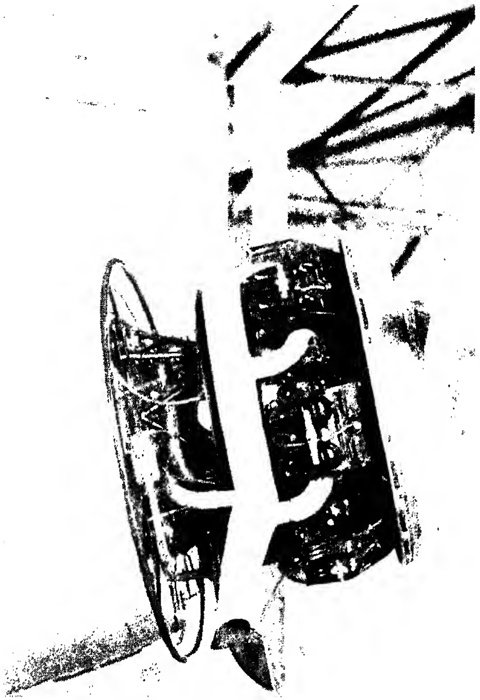


Fig. 8.—A LOW-POWERED RADIAL INSTALLATION.

plane. The fuel tanks may be either installed in the upper or the lower main planes, and either 2, 4, or 6, in number.

Taking four tanks as an example, these will be interconnected in pairs, the interconnecting pipe lines or flexes being controlled by cocks. The system may be of the gravity feed type to the pumps installed on the engine, from whence the supply to the engine will be under pressure, usually from 2 to 4 lbs. pressure per square inch. A relief valve is normally incorporated in the fuel pump to allow of adjustment to suit the type of carburetter employed.

It is usual to balance the fuel system so that, in the event of one pump ceasing to function, the pump on the second engine will maintain an adequate supply of fuel to both. This is known as balancing the pressure side.

An alternative is to balance the gravity side of the system by taking a branch line from one side and interposing it into the gravity feed line on the opposite side. In both cases an isolating cock is provided, chiefly to ensure that both systems are functioning satisfactorily, when checking the fuel system on the daily inspection. In flight, this cock should be open.

Jettison System

A jettison system is often incorporated to enable all fuel to be jettisoned in case of emergency. The jettison valves are built into the fuel tank sumps and take the form of a spring-loaded valve having a large flat head. The spring is loaded to approximately 40 lbs. per square inch

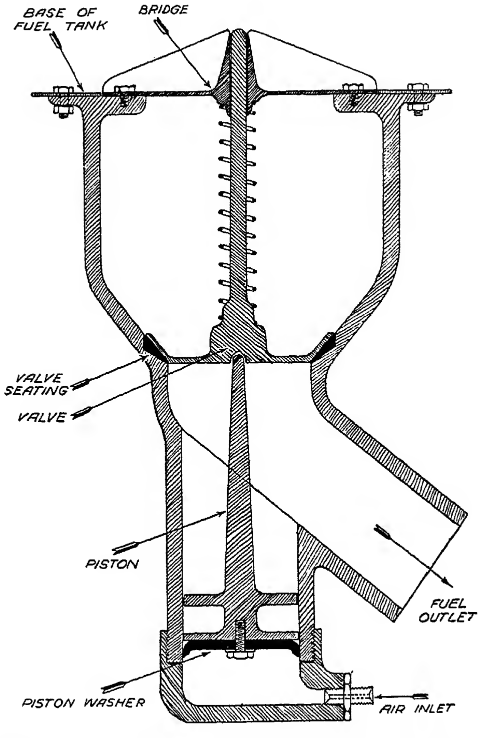


Fig. 9.—PRINCIPLE OF OPERATION OF FUEL TANK JETTISON VALVE.

and is operated by means of compressed air. These valves must be fuel tight and the air supply system checked for holding the pressure for a fixed period with all valves in the open position to ensure that full tanks can be jettisoned before the air supply is exhausted.

Each tank jettison is controlled by a cock with a master cock to control all pipe lines. This should have some form of guard to prevent accidental operation.

Gravity Fuel System

If the fuel system is of the gravity type, the supply line should have a steady fall from tank to carburetter. Petroflex and Superflexit are extensively used, in combination with seamless copper or stainless steel pipe lines. Rubber hose joints are not employed for joints in the latter—these being of the metal coupling type. The ends of the pipe lines are belled to receive the olives or adaptors, and care should be taken that these are fitted correctly and that they do not trip when tightening up the joint. All joints are wire locked in such a way that slacking off is resisted.

All pipes should bear evidence of previous inspection before embodiment in the system and should carry their part numbers on a tab sweated to the pipe. This facilitates identification when ordering replacements.

Bends in flexes are to be within the limits laid down by the makers. The belling of the pipe ends should be closely inspected for signs of flaws and cracks due to hardening of the material when being worked.

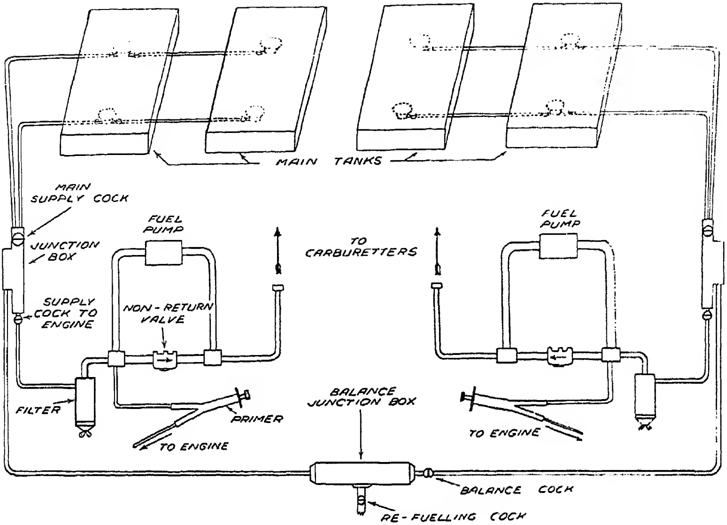


Fig. 10.—TYPICAL FUEL SYSTEM FOR TWIN-ENGINED INSTALLATION.

All pipe lines should be adequately supported in clips and the line to the carburetter should be either of Petroflex or Superflexit. If the engine is flexibly mounted, sufficient slack should be allowed, as the movement of the former is considerable when " ticking over."

The fuel tank may be provided with both front and rear sumps, in which case the supply lines will be taken from both and meet at a point near the nacelle, a junction box being provided for this purpose. A supply line is then taken to a large A.G.S. fuel filter.

From this point the fuel passes to the engine-driven pump, which may be either single or dual. Passing from the pump it is fed to the carburetter float chamber under pressure.

Combined Gravity and Pressure System

In a system combining gravity with pressure, a branch will be taken from the gravity-fed junction in both nacelles and coupled together, with a remotely controlled cock interposed between the two. Fuel can flow to the carburetter by gravity by short-circuiting the fuel pump. To do this, a one-way valve is interposed between the supply line to the fuel pump and the outlet line from the same. A fuel pressure gauge connection must be inserted at some point in the system between the pump outlet and the carburetter connection (see fuel system diagram).

A primer is normally fitted to assist starting and should be installed

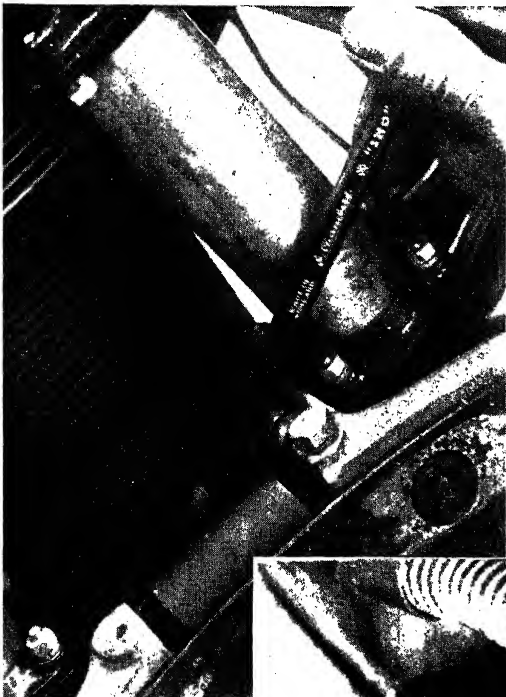


Fig. 11.—THE LORD-TYPE FLEXIBLE MOUNTING UNIT.

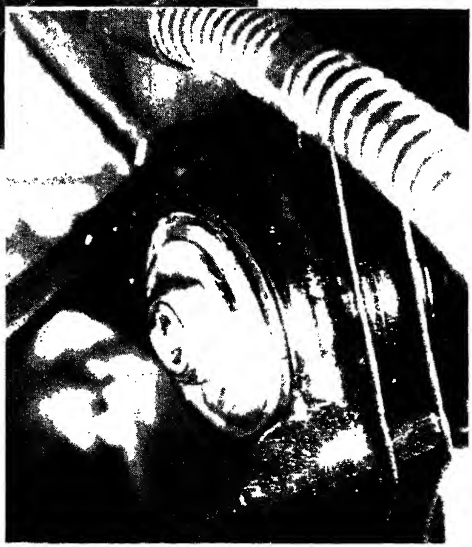


Fig. 12.—SOME SMALL INSTALLATIONS HAVE THE MOUNTING ITSELF MOUNTED ON RUBBER, AS ABOVE.

Fig. 13.—THE DEEP CHORD COWLING, EMPLOYED ON THE SMALLER TYPES OF ENGINES.

so as to be accessible for use without removing any portion of the cowling and should take its supply from the gravity side of the fuel system, where possible. A flexible pipe should also be used between the primer and the connections on the engine and adequately clipped up to prevent chafing.

When fuel tanks are installed below the pump level, it is important

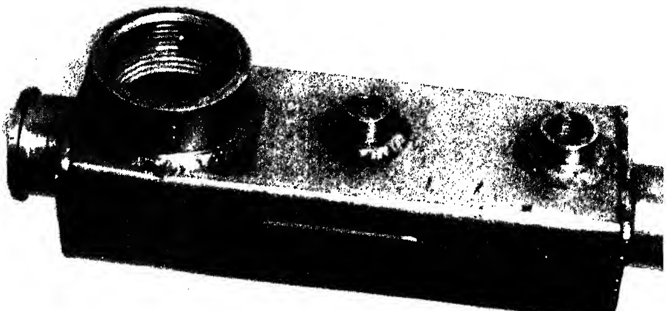


Fig. 14.—THE JUNCTION OR COLLECTOR BOX.

Fig. 15.—Showing the correct assembly of the A/M type of coupling.

that all joints should be tight and so avoid suction leaks which will reduce the output of the pump.

The fuel tanks should be provided with drain cocks at the bases of the sumps to allow of periodic draining of any accumulation of foreign matter—*i.e.*, water, etc. These cocks are normally locked in the closed position.

Should it be necessary to alter the length of either Petroflex or Superflexit, the flexible hose must be subsequently pressure-tested to 15 lbs. per square inch for the former and 50 lbs. per square inch for the latter. Some of the larger aeroplanes have provision made for refuelling by means of an auxiliary power unit. This will involve interposing a pipe line into the gravity balance line to enable the fuel to pass into the main tanks. Large capacity air vents will then be necessary at the latter. After the system is completed it should be tested for flow, with 10 per cent. of fuel in the tanks and the aeroplane inclined 10 degrees down aft.

Fig. 16.—Method of locking coupling. The flex is correctly locked. The steel pipe incorrectly.

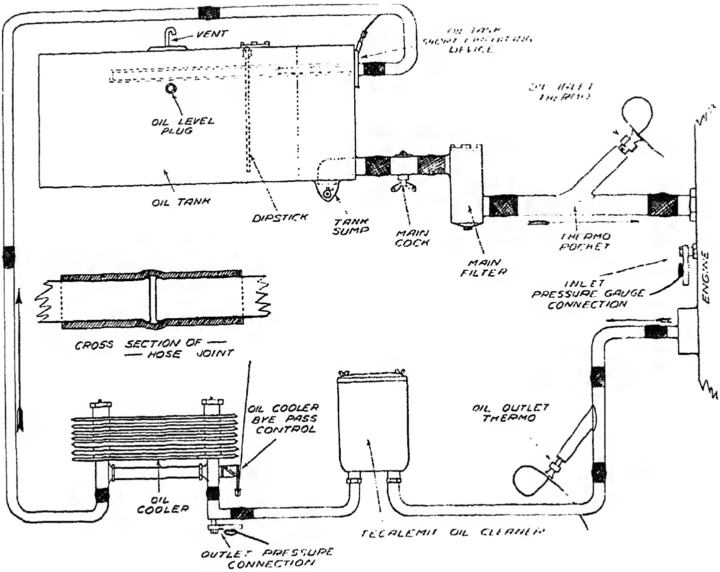


Fig. 17.—OIL SYSTEM DIAGRAM FOR HIGH-POWERED INSTALLATION.

Oil System

On small installations with wet sump engines, all that will be necessary is an oil-pressure gauge and usually an oil-outlet thermometer. With the example being considered, however, a twin-engined aeroplane of the heavier type, oil tanks will be installed and possibly oil coolers.

The oil tanks, where possible, are installed so that some portion is exposed to the slipstream and so assists cooling of the oil. They may be built in to form part of the main plane leading edge.

Rubber hose is employed for making the joints in the pipe lines and these are clipped and bonded.

The outlet pipe from the oil tank should be of sufficiently large diameter to offer little resistance to the passage of the oil to the pump when cold. A filter of coarse mesh must be inserted in the pipe line and should be easily accessible for inspection in service.

An oil cooler is employed in the larger installations, usually of five to nine elements. The outlet pipe from the engine choke jacket or pump is first taken to a filter or cleaner. The oil should then pass to the cooler before being returned to the oil tank. The former should be rubber mounted to absorb vibration.

A bye-pass valve embodied in most coolers allows the elements to be

short-circuited to reduce the time taken in warming the engine. The cable operating this valve is checked to ensure that the valve opens and closes fully. An oil-pressure gauge is essential and provision is usually made on the engine for its connection.

The transmitting type is now in more general use, as a broken capillary does not involve loss of oil. An outlet and an inlet thermometer are fitted to the larger engines and a Y-shaped pocket must be inserted in both supply and return lines to accommodate them. When installing these it should be noted that they lie in the right direction, that is, the single leg of the Y or pocket should be on the side from

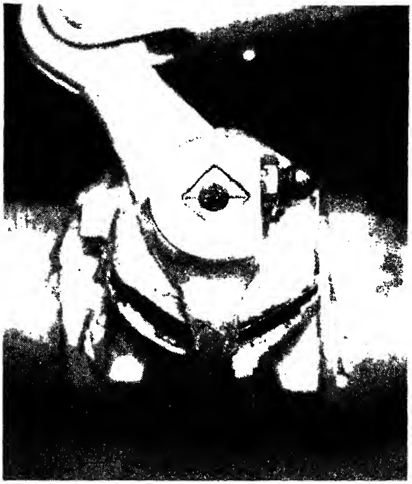
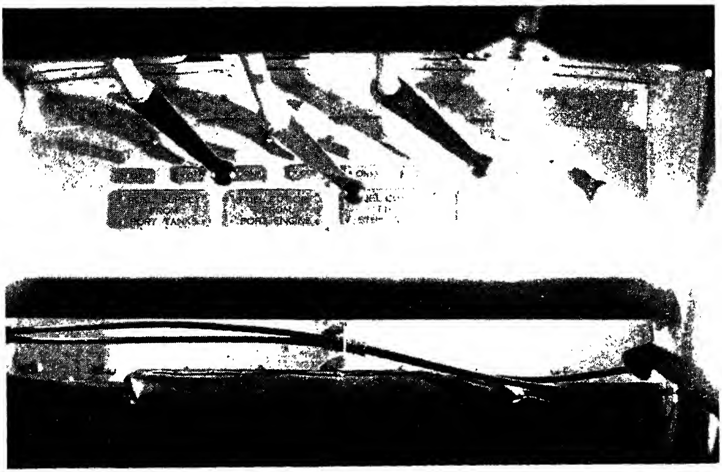


Fig. 18.—The pointer on the cock lever must butt hard up against its stop.



–Showing the cock control levers and the stop pins. ‘On” and “— —’ positions must be clearly indicated.

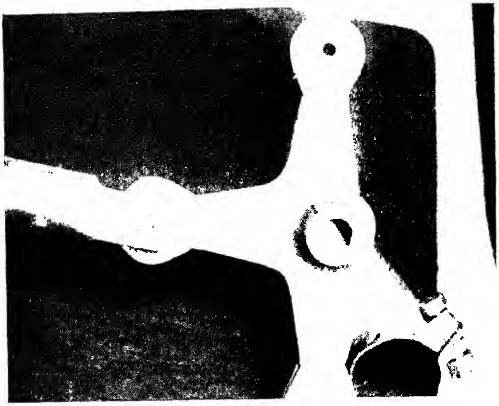


Fig. 20.—LEVERS MUST NOT TRAVEL TOO CLOSE TO T.D.C.

which the oil is passing. The outlet pocket is also installed as near to the engine as possible to ensure true readings.

An outlet oil-pressure gauge is sometimes fitted. This should also be close to the outlet point on the engine. The outlet pressures obtained vary with the design of the system and may range from 6 to 40 lbs. per square inch under normal running conditions.

New installations should be primed before starting the engines by slackening off the filter cap and so venting the pipe line.

Certain types of oil tanks are provided with a short circuiting device which allows a small quantity of oil to pass back into the feed line after being returned from the engine. This is spring loaded and operated from either the pilot's or the engineer's seat, by means of Bowden cable. It should be checked for functioning to ensure that full travel is obtained.

The oil cooler is normally mounted where the slipstream will impinge upon it whilst causing the minimum of drag or resistance. Copper pipe lines are not normally pressure-tested after being shaped and the ends belled or beaded, but where stainless steel is used, this is pressure-tested to 50 lbs. per square inch.

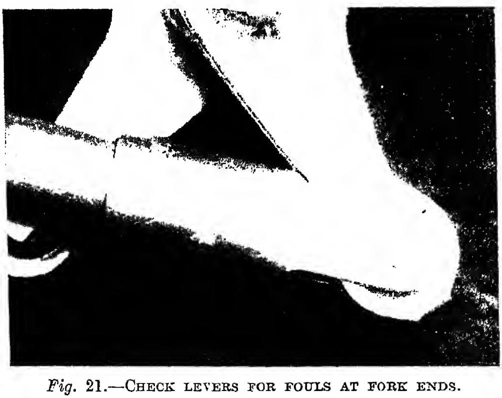


Fig. 21.—CHECK LEVERS FOR FOULS AT FORK ENDS.

An alloy known as "Tungum" is now being used and the insides of bends in pipe lines of this material should be carefully inspected

for signs of cracks and folds.

All pipe lines should be "pulled through" and washed out before installation to ensure freedom from flakes of lead or resin, used for loading the pipe during bending.

When installing the pressure and thermo gauges and capillaries, care should be taken in uncoiling the latter and so preventing twisting of the small diameter tubing. They must not be cut, any surplus length being carefully coiled and supported in the engine nacelle. Where the capillary leaves the connection at the engine or thermo pocket, a small $2\frac{1}{2}$-in. single coil should be made and clipped to the flared portion of the top of the bulb. This is to prevent possible fracture at this point. Where it passes over small edges at any point of the structure, it must be protected by means of Systoflex

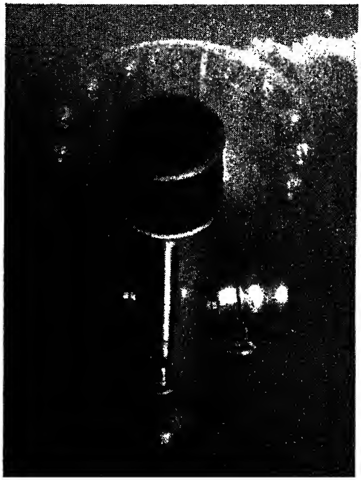


Fig. 22.—The fuel tank jettison sump built into the floor of the fuel tank.

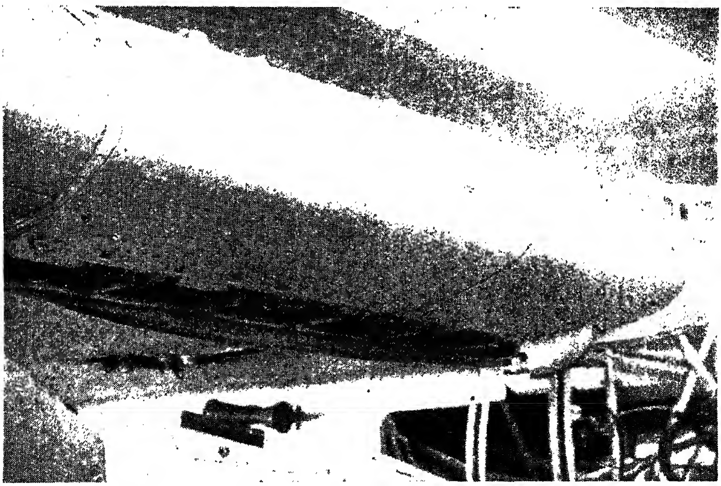


Fig. 23.—The oil tank. Built into the leading edge of the wing, an ideal position.

Fig. 24.—THE OIL THERMOMETER-POCKET WHICH HOUSES THE BULB.

or similar material. Replacement of these instruments due to faulty installation often entails a large amount of work, so all possible precautions should be taken during initial installation.

Throttle and Mixture Controls

These controls may be a system of pull-push rods, torque shafts, and levers or of the Arens or Symonds Corsey type.

The throttle controls must move forward to open and the mixture controls forward to weaken the mixture. After installing these controls, the direction of travel should first be checked to ensure that this is correct. The range should then be checked to ensure that the throttle fully opens and closes. A ·002″ feeler or a piece of thin paper should be inserted at the carburetter stops and should be tightly gripped when the control is moved to the extreme position. The fully open position on any carburetter can be easily distinguished from the fully closed by the fact that an adjustable stop screw is only fitted at the latter.

When checking controls on an engine of the supercharged type having automatic boost control, it is essential that the link work on the carburetter be held hard up (Fig. 31). If the movement and range are correct, the complete system should be checked through from carburetter to control quadrant to ensure that no fouls are taking place, all adjustable fork ends are locked and in safety and that

Fig. 25.—OIL PIPES SHOULD HAVE THEIR ENDS BEADED IN THIS WAY AT ALL HOSE JOINTS.

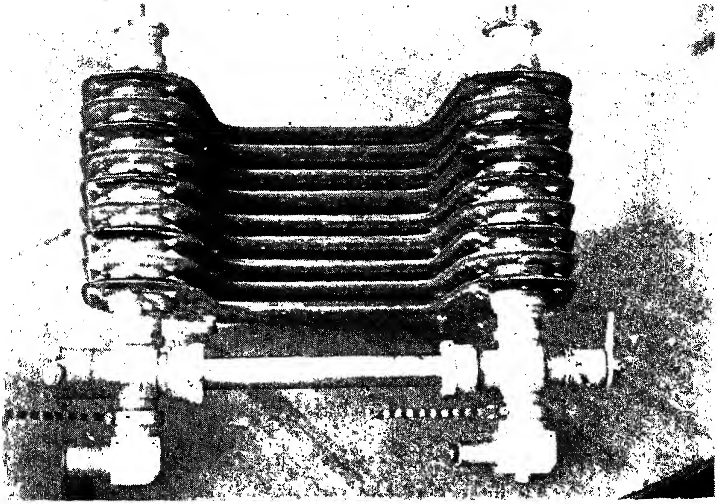
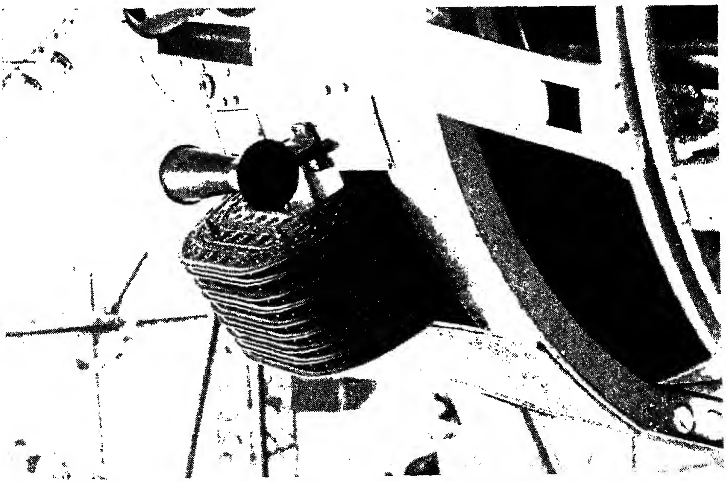


Fig. 26.—A 9-ELEMENT OIL COOLER. THE BYE-PASS LEVER IS SEEN ON THE RIGHT-HAND SIDE.



27.—THE OIL COOLER INSTALLED ON THE SIDE OF THE ENGINE NACELLE, WHERE IT IS EXPOSED TO THE AIRSCREW SLIPSTREAM.

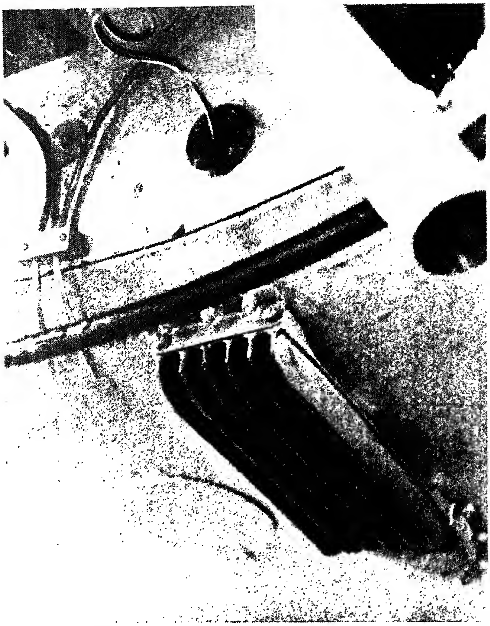


Fig. 28.—A SMALL OIL COOLER SUITABLE FOR LIGHT INSTALLATIONS. THE FUEL PUMP DRAINS WILL BE NOTED, LEADING OUTSIDE THE COWLING.

Fig. 29.—THE EXHAUST EXPANSION JOINT.

no levers tend to ride over top dead centre. A stop should be incorporated at the throttle quadrant to prevent too great a load being placed on the system after the lever on the carburetter reaches the "fully open" stop; this should be adjustable.

The mixture controls are checked in a similar manner. The control cock in the carburetter is usually marked with the open and closed positions, but where this is not known and no means available for finding out, the cock can be removed for a check. The open or weak position will be that where the slot in the housing and the slot in the body of the cock coincide. All throttle and mixture controls must be so designed that, with both fully open, closing the throttle will bring the mixture control back to the closed or rich position. This is checked to ensure positive operation.

In the case of supercharged engines, three positions are indicated on the

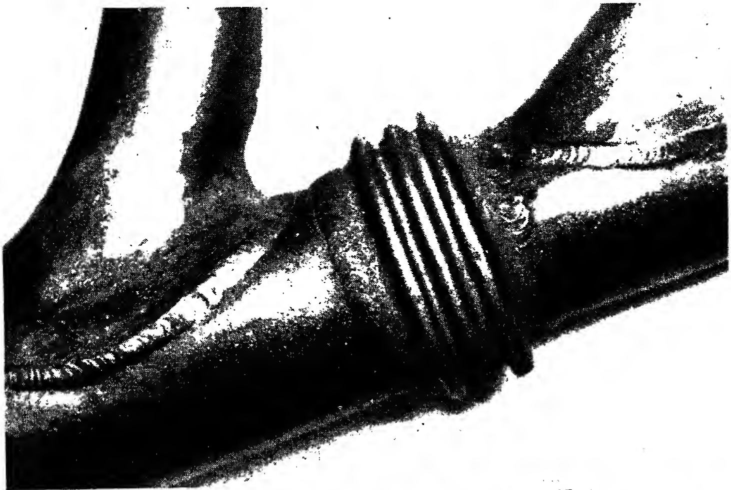


Fig. 30.—ANOTHER FORM OF EXPANSION JOINT.

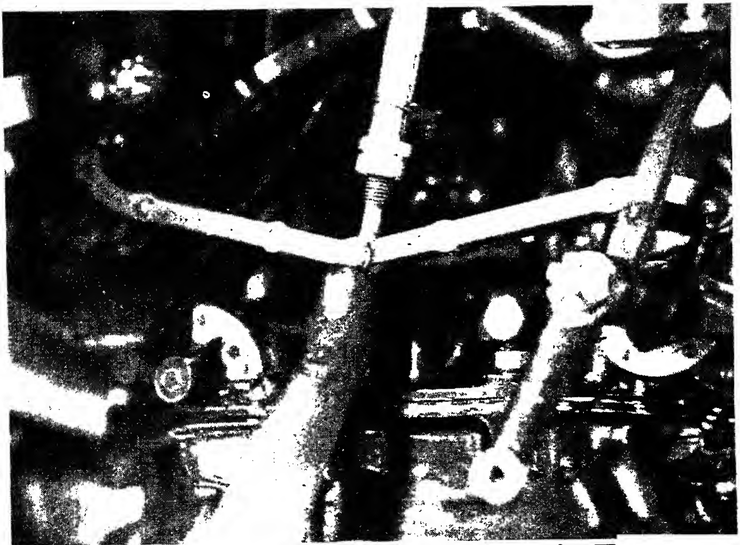


Fig. 31.—THE LINK MUST BE HELD UP WHEN CHECKING TRAVELS ON THE OF SUPERCHARGED ENGINES EMPLOYING AUTOMATIC BOOST CONTROL.

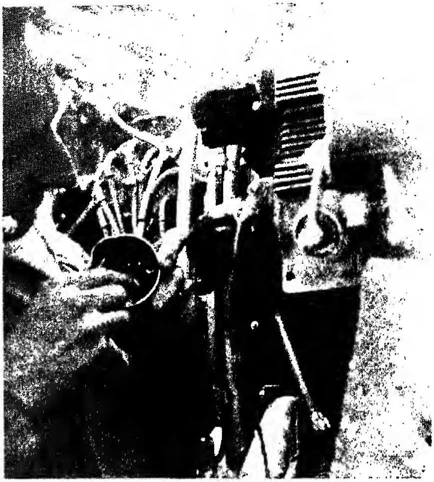


Fig. 32.—LOW-TENSION SWITCH WIRING CHECKED BY BUZZER AND BATTERY.

cock—*i.e.*, weak, normal, and rich. Closing the throttle should bring the cock to the normal position. To obtain the rich or maximum boost position, the lever is passed through some form of gate and moved further back.

It should be noted when checking this that the over-riding device at the automatic boost control depresses the aneroid spindle. With this type, a further check is necessary. The throttle control lever does not begin to return the mixture control at the commencement of its travel but several degrees of movement later. An indicator plate on the carburetter is marked to indicate the point at which this "pick up" should occur. This should be within 5 degrees of throttle spindle movement, early or late. It is better that it should be on the early side.

After these checks, it should be noted that both throttle levers (in the twin-engined installation) synchronise in both the full open and closed positions. On certain small single-engined installations no provision is made for operation of the mixture control cock, in which case the cock is securely locked in the closed or rich position.

Fuel Cock Controls

On large installations these are remotely controlled. In the present example taken, they will be six in number. Two will control the supply from the two pairs of fuel tanks and two others control the supply to the two engines. The fifth will be the balance cock which will put the port side of the system into communication with the starboard side and the sixth will be the re-fuelling cock.

After installation the cocks should be checked for direction of travel. The cock spindle will have a line cut diagonally across the squared end, the cock being open when this line is fore and aft along the body of the cock. In this position the cock handle or pointer should register with the "open" marking. They should then be checked for travel. This is important. The finger on the cock lever must butt hard up to the stop

ring on the cock body in both the open and closed positions. Stops must also be provided at the cock handles against which the cock control lever must butt.

Regulations state that the pilot must be able to cut off the fuel supply from the control cabin, so that, if the controls are normally operated by the engineer, the two engine supply cock controls must be extended to the control cabin. All cocks must be clearly labelled to indicate their nature and their operating positions. They should also be painted to indicate at a glance whether they are port or starboard. (This point also applies to throttle and mixture controls.)

The system should be free from backlash, whether new or in service and should be free to operate. The same points in the system should be checked as on throttle and mixture controls, all bolts being securely locked. A certain amount of wear is inevitable when the aeroplane is in service, particularly when a number of ball joints are incorporated in the system. This should not be allowed to develop to the point when the range is so reduced that less than 90 degrees travel is obtained at the cocks.

Cooling System

This may be either by air or liquid. The majority of civil installations are of the former type. Air-cooled engines are supplied by the makers, complete with intercylinder baffles and air chutes. These should be securely attached so that no movement, relative to the cylinders, is possible. In the case of air-cooled in-line engines, the area of the chute aperture in the nose cowl should not be below the minimum stated by the makers of the engine. In the case of liquid-cooled engines, the radiator and its suspension points should be closely inspected to ensure that no point will chafe against surrounding structure when the engine is running. Inlet and outlet hose joints should be securely clipped and bonded (the latter where necessary).

Care should be exercised in handling the radiator during installation in the aeroplane.

If of the retractable type, the operating gear should be checked for freedom and functioning. A drain cock must be provided at the lowest point in the system and the supply from the radiator to the pump or pumps should have a steady fall. An outlet thermometer is fitted either in the header tank at the top of the radiator or else at the forward end of the outlet pipe from the engine. Where radiator shutters are fitted, they are checked for fully opening and closing and for being positively locked in any intermediate position.

Exhaust System

Small type engines may be either fitted with stub pipes, a manifold or collector rings and tail pipes. The exhaust gas must be carried clear

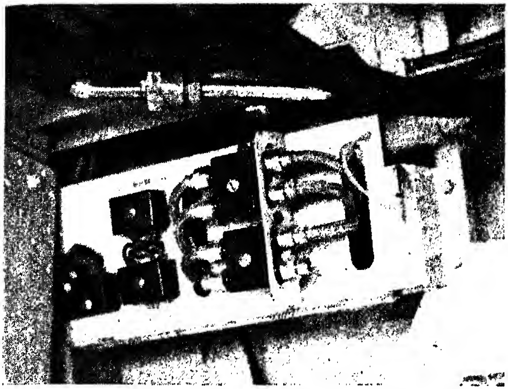


Fig. 33.—THE CONNECTORS EMPLOYED WHERE A BREAK IN THE CABLE RUN IS FOUND NECESSARY.

of the aeroplane and not allowed to impinge on any part of the structure. This point should be noted when running the engine, as the slipstream may carry the exhaust gas on to a strut or cowling panel, although the outlets may not be in line with it. If a tail pipe is fitted and secured to the airframe, provision must be made for expansion. This may take the form of a sleeve joint or the bracket may be spring loaded. In the case of a number of static radial engines, the collector ring is rubber mounted, the shock-absorbing elements being carried at the outer ends of the support stays, the latter being anchored to the engine crankcase. An intermediate and short tail pipe are carried on a support bridge bolted to the head of one of the cylinders.

The joint between the outlet pipe of the exhaust collector ring and the intermediate pipe should be a good sliding fit, with the minimum of clearance. This is important, as a poor fit at this point would allow hot exhaust gas to escape underneath the Townend ring with consequent drying-up of the valve stems and probable seizure of the latter.

When manifolds are fitted to a Vee or In-line engine, some form of washer must be fitted between the exhaust ports at the cylinder heads and the manifold flanges. These are usually of copper and asbestos. Although these washers are soft, they are not used to correct any malalignment of the manifold flange, which should be checked for truth by means of a straightedge before bolting home. It is usual to drill a small drain hole in the exhaust collector ring at its lowest point on radial engines to allow any accumulation of oil to drain away whilst the aeroplane is standing. This prevents accumulated oil being thrown out at the tail pipe when the engine is started up and being thrown out over the main plane and tail structure. Where there is any danger of exhaust gas being carried on to the nacelle or main plane, it is usual to fit some form of guard or flash plate of aluminium or duralumin sheeting.

Ignition

The ignition L.T. wiring from the switches to the main engine mag-

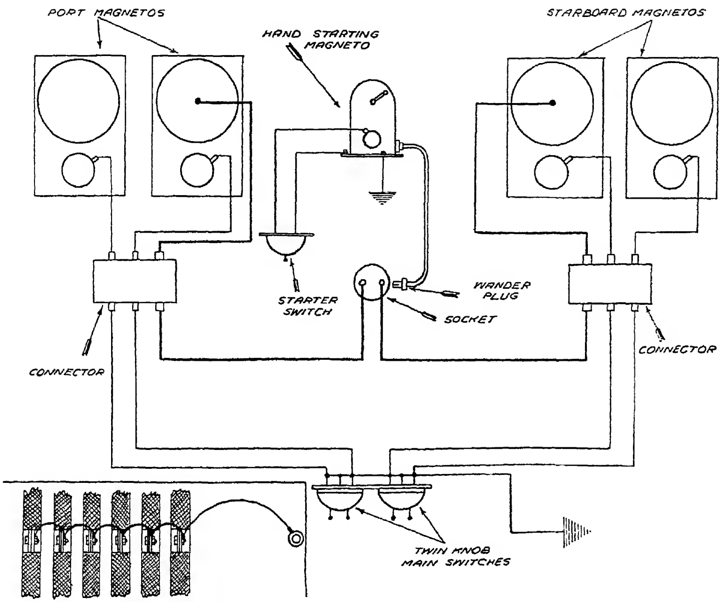


Fig. 34.—IGNITION WIRING DIAGRAM FOR TWIN-ENGINED INSTALLATION.
Bottom left-hand corner shows method of bonding cable-braid to earth behind main switches.

netos may be of the plain insulated type if W/T is not carried, otherwise the metal braided type known as "Unisheath" must be used. The latter is standard on the majority of installations. There are two sizes in use, $5\frac{1}{2}$ mm. and $7\frac{1}{2}$ mm., the former for low tension circuits and the latter for high tension.

Starters

One of several systems may be employed. Electric starters are fitted by a number of manufacturers and operate in combination with hand-turning gear.

The two starter terminals must be provided with rubber insulating guards to prevent accidental short circuiting. The commutator must be accessible for cleaning purposes and the wiring tested for insulation resistance by means of a 500-volt Megger. The hand-starting magneto is often interconnected with the electric starter and mounted in the nacelle, being driven by chain.

If a gas starter distributor is used, the pipe line should be pressure-tested to 100 lbs. per square inch and checked for leaks. If the engine is rubber

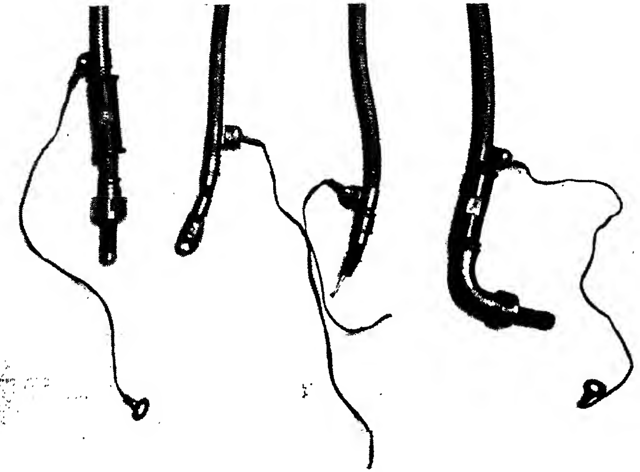


Fig. 35.—THE METHOD OF FINISHING OFF THE METAL-BRAIDED H.T. AND L.T. IGNITION CABLE.

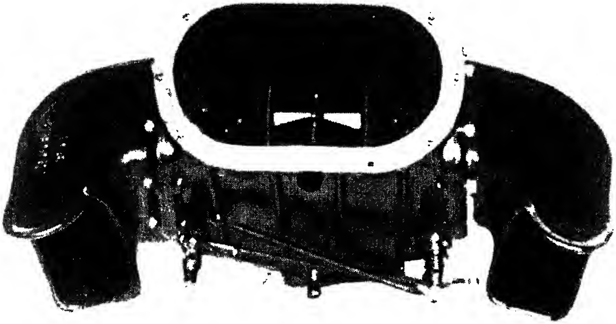
mounted, it is advisable to put a coil in the pipe line, directly it leaves the inlet connection at the distributor, to absorb vibration.

If an inertia type starter is fitted to the engine, the clutch must be checked for the correct function of throwing out.

Cowling

The cowling is usually built up on some form of jig and should be checked for evidence of inspectional clearance for that stage. That in small light-engined aeroplanes is comparatively simple, while that on a nacelle built into a main plane is more difficult to manufacture. The framework carrying the various panels should be checked for being securely anchored to the engine mountings. The panels should be capable of easy removal whilst being firmly held when in position. They must also be stiff enough to prevent "panting." When the nacelles are similar in contour, it is advisable to stencil Port and Starboard inside the respective sets of panels, to facilitate servicing the engine. It should be noted that the louvres or openings in the side panels have their openings facing aft and are correctly positioned.

The Townend rings form part of the nacelle fairing and are mounted either directly on to the engine rocker boxes or else carried on a flange formed at the rear of the exhaust collector ring and a rear support ring carried on brackets attached to the cylinder heads. They must be securely located to prevent fore and aft movement. The rings are usually



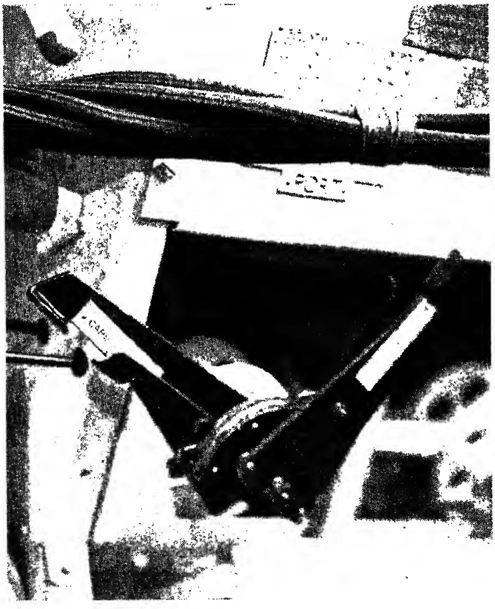


Fig. 36 (*above*).—SHOWING THE AIR INTAKE SHUTTERS.

Fig. 37 (*left*).—THE AIR INTAKE SHUTTER-CONTROL LEVER AND INDICATOR PLATE.

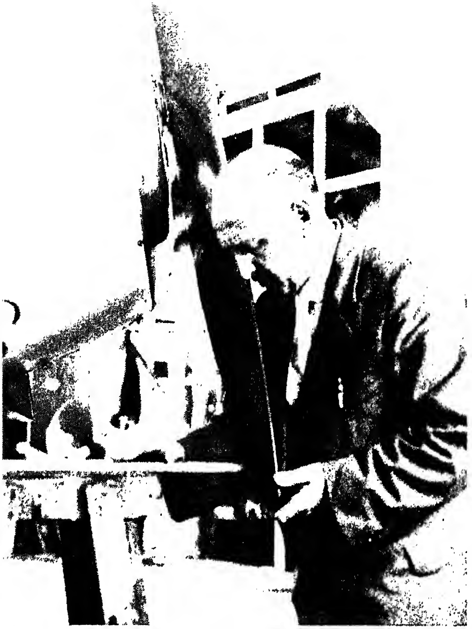


Fig. 38.—THE AIRSCREW IS CHECKED FOR TRACK.

in two or more sections joined together by clamp plates. The ring is usually of either aluminium or duralumin sheet, and reinforcing steel strips should be riveted to the ring where it sits on both the exhaust ring flange and the rear support ring.

Drainage must be provided at the lowest point to prevent fuel or water from accumulating and being drawn up through the air intake when starting up. If controllable gills are fitted, as in some later types, the operating mechanism must be free in action be locked in any one position. As with the cowling panels, the rings should be stencilled Port and Starboard.

Airscrews

If the airscrew being fitted is of the fixed pitch wooden type, it should be assembled on to the hub and checked for track. Prior to fitting it should be confirmed that it is approved for use on that particular installation. Limits are laid down for error in track, according to the diameter, but before rejecting one that is slightly outside the limit, the engine should be ground tested, and, if possible, flown, as it frequently happens that no ill effects are observed owing to this error.

After the initial run, the airscrew hub bolts must be checked for tightness, as the new plate may settle down at the boss face.

The nuts are then locked, either by split pins, tap washers or locking plates. If of the fixed pitch, built up, light alloy type, the airscrew must be assembled to the makers' instructions. The Fairey three-bladed metal airscrew is an example of this type. The hub should be offered up to the

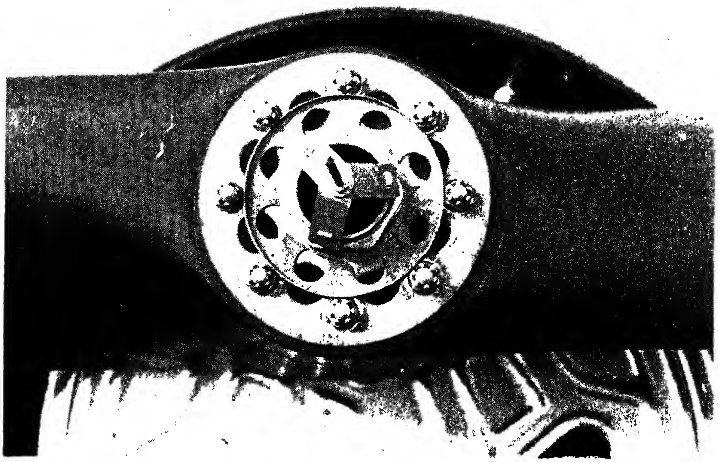


Fig. 39.—HUB BOLTS ON SMALL INSTALLATIONS MAY BE LOCKED BY MEANS OF A LOCKING PLATE, IN THIS WAY.

airscrew shaft before assembly to ensure that it sits home on the shaft splines. A paste of white lead and tallow or a graphite paste is smeared over the splines when assembling the airscrew to the engine.

In the case of the oil-operated variable pitch airscrews, the makers' instructions reassembly must be followed. The oil control valve is checked for free operation and travel. The oil supply connection at the forward end of the reduction gear case should be observed for leaks on the first engine run. On airscrews of this type, the limits in track error must be closely observed. During the assembly of all light alloy airscrews the blades should be supported to avoid possible distortion.

Carburetter Slow-running Cut-out

This device is fitted to the majority of large carburetters and is operated from the control cabin or cockpit by Bowden or flexible cable. When fitting these control cables, it is extremely important that they should be free in operation and that the cut-out plugs return to their fullest extent on the lever being released. A servo spring is incorporated in the run of operating cable to assist this return. When fitted to a rubber mounted engine, there must be sufficient slack in the cable, in the free position, to allow for movement of the engine.

In the case of twin carburetters the control is by a single cable and care must be taken to ensure that both plugs have their movements

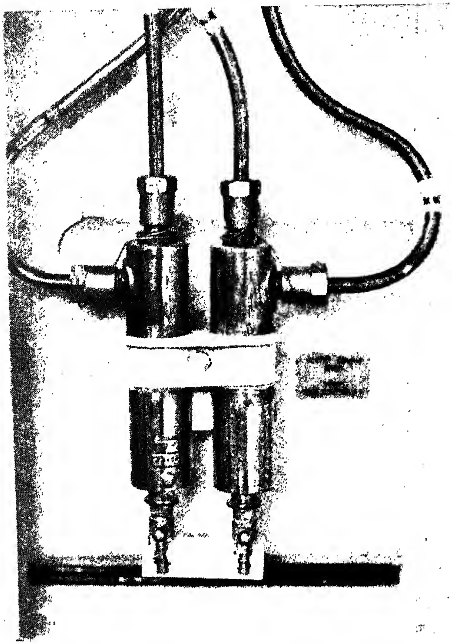


Fig. 40.—A DRAIN SUMP SHOULD BE PROVIDED IN EACH BOOST GAUGE LINE.

synchronised. The direction of the control lever travel must be clearly indicated.

Air Intakes

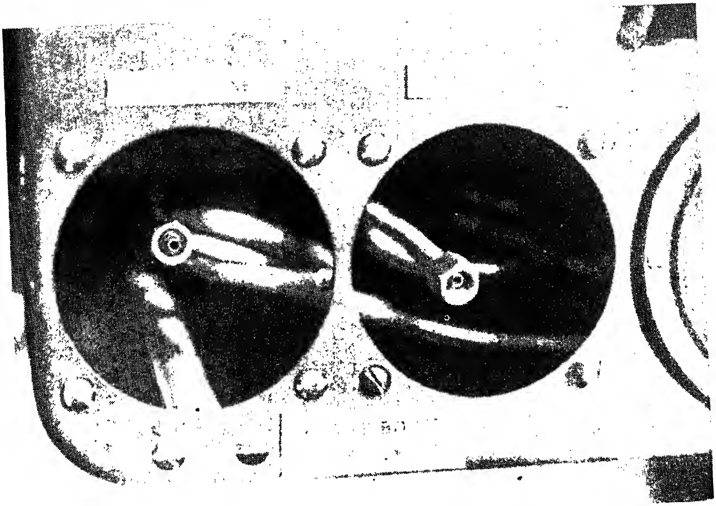
The air intake is normally supplied with the engine, although on some light installations the flange only may be supplied, the intake being made to suit the contour of the particular nacelle. In this case the bore of the intake must not be less than that of the hole in the flange and abrupt bends avoided. It must also be adequately drained in the tail-down position. the drain pipe being brought outside the cowling. (This applies to all drains in the engine installation.)

The larger type air intakes are supplied with shutters to allow of warm air being drawn in, through collectors sitting close to the cylinder heads. These are remotely controlled by cable and should be checked for freedom and full travel in both the open and closed positions.

Engine-driven Generator

An engine-driven generator is supplied on the larger engines to provide current for the general service and starter batteries, and may be either mounted directly on the rear of the engine or at the rear of the engine nacelle and driven by means of a flexible drive shaft. In either case, an air intake is fitted to assist in cooling the generator whilst running under normal conditions. When mounted on the engine itself, a carden shaft gives the drive through ferodo discs. The alignment of the generator and its drive should be checked and the commutator cover should be accessible for cleaning purposes.

When a flexible drive is employed, the drive and its casing should have



g. 41.—The boost lines should be coiled between the engine and the instrument to absorb vibration.

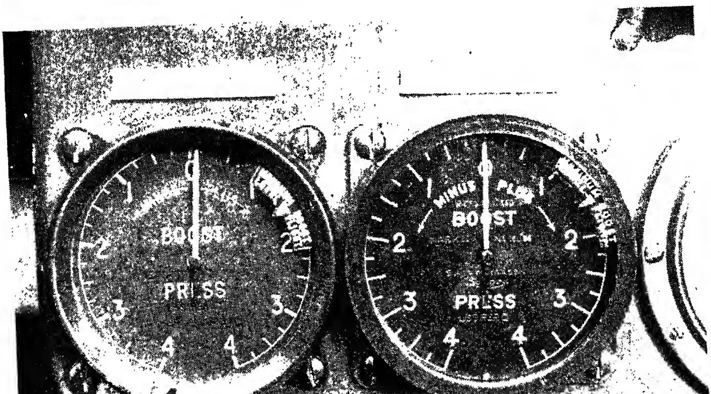


Fig. 42.—The boost gauges showing the adjustable sector. These have been moved to show + 1½ lbs. for Bristol Pegasus III M engines.

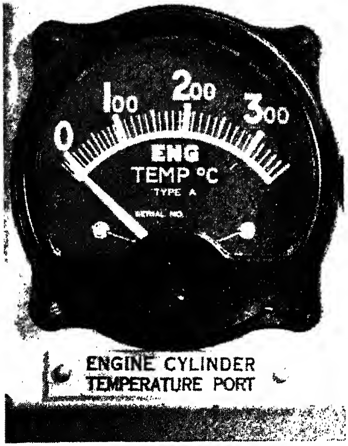


Fig. 43.—THE CYLINDER TEMPERATURE GAUGE. (180° TO 190° C. IS AN AVERAGE TEMPERATURE.)

as large a radius at bends as possible to reduce friction and wear of the shaft in its casing. It must also be checked for freedom from end loads, which will cause rapid heating up and possible seizure. A stowage block of some description must be provided for the three generator leads, should the generator be removed temporarily.

Boost Line

$\frac{1}{4}$ or $\frac{5}{16}$ in. o.d. copper tube is employed and joints in the pipe line must be of the metal union type except at the connection on the engine gas case, where this will be of rubber hose.

The line should have a steady fall from the engine to the boost gauge and a drain sump fitted at its lowest point to allow of a periodical draining of condensed fuel vapour that may collect in the pipe line. It is advisable, with flexibly mounted engines, to form a coil in the pipe line immediately behind the engine to absorb vibration and movement. Before coupling up to the instrument, the line must be pressure-tested to 10 lbs. per square inch for five minutes. The line must also be coiled immediately behind the instrument.

Revolution Indicators

The drive is of the flexible type and is short in length when the electrical indicator is employed, usually 12 to 18 in. long. If the indicator is of the mechanical type, it is important to keep bend radii as large as possible, to obtain steady readings and reduce wear to a minimum.

The electrical type, such as the R.E.C., employs a small generator mounted in the nacelle, the current generated being conducted to the instrument by means of Ducel cable. The generator must be so mounted that it is above the engine end of the flexible drive shaft in order to prevent grease or oil passing down the drive casing and entering the generator casing.

The foregoing remarks cover the average installation, although additional accessories are often incorporated, such as vacuum pumps, air compressors, etc. The pipe lines from these auxiliaries should be pressure-tested according to their duty in the installation.

ASSEMBLING THE AIRSPEED ENVOY

By J. B. Matthews

The centre section with the undercarriage attached is placed on trestles of the screw-jack type, each trestle having two jacks which are so made that their centres pick up the extension 'plane attachment fittings, with the centre section in position; the fuselage can now be lowered using two blocks and tackle. Care must be taken during this operation to be sure that in slinging, the fuselage will not foul the spars as it is lowered. Once in position the necessary bolting up can take place.

With the fuselage now attached to the centre section, proceed to adjust the fuselage by means of the screw jacks and packing of the tail trestle until the datum lines are truly horizontal both longitudinally and laterally. (Fig. 1.)

To effect these adjustments, a straight-edge and spirit-level are necessary. Place the straight-edge with the spirit-level on the blocks provided; these are to be found inside the luggage locker.

Rudder

The next operation will be the fitting of the rudder to the fin-post; first fit the top hinge pin, then the bottom and finally the centre pin.

The tie rods can now be attached to the rudder intermediate lever. A method used is to fit the two right-hand threaded fork-ends on the inner holes of rudder intermediate lever by means of an A.G.S. pin, then screw the rod into the fork-end, counting the number of complete turns, say three, then take the two left-hand fork-ends and screw them on with the same number of turns; in so doing, make sure that the tie-rod is held, the rods can be screwed into the fork-ends and connected to the levers on the rudder which are held in position by an A.G.S. pin.

The rudder may now be trued up in the following way: adjust the tie-rods until, with rudder aligned fore and aft, the intermediate lever runs parallel with the bulkhead. Rudder main cables can now be attached, this being necessary before attaching the tail plane.

Note. All hinge pins and A.G.S. pins fitted where movement has to take place should be well greased at the time of fitting.

Tail Plane

Attachment fittings being already in position, the tail plane can be inserted, care being taken to keep it level. By using tapered bolts to locate the holes, it will be found quite easy to follow through with the correct bolts, thus avoiding any damage likely to occur to the threads through not having a fair hole.

The tail plane adjusting unit or what is better known as the " Tail

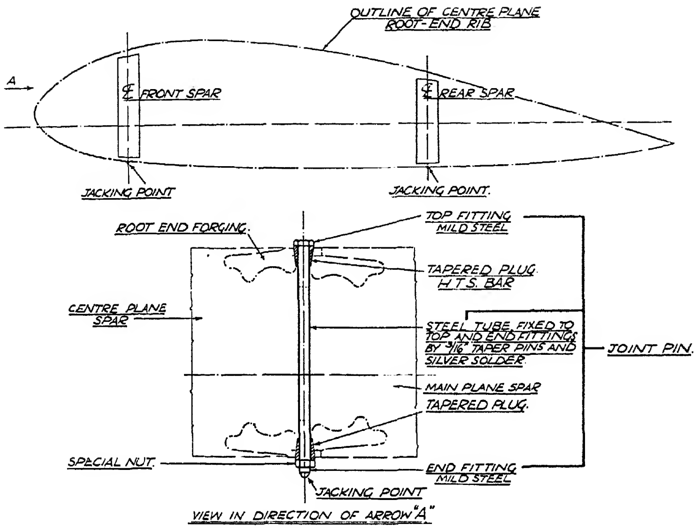


Fig. 1.—DIAGRAM SHOWING JACKING POINTS.

Jack " can now be fitted, but before doing so, the following points should be noted :—

(i.) See that it is possible to get the full up and down movement before attempting to place it in position.

(ii.) See that it is fully contracted with the bobbin and top of jack screwed right down with one and a half turns of cable remaining on bobbin.

(iii.) The indicator which is attached to the wheel control in cockpit should be at maximum tail down position.

The jack may now be fitted by passing the top end through the fitting in the centre of tail plane and lowered to its position of attachment at bottom of fuselage. Make sure that the bushes and distance pieces supplied are in position and that the whole unit has been well greased. The bottom attachment bolt should be fitted first ; this being done, the tail plane should be lowered on to the top of the jack and the special bolt provided fitted. A fibre fair-lead is fitted to the bulkhead for the purpose of taking the cable ends. These should be passed through and coupled up on the inside of the fuselage.

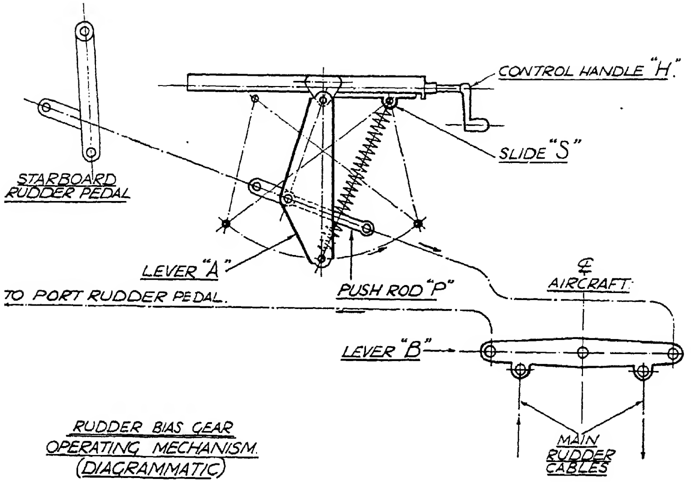


Fig. 2.—RUDDER BIAS GEAR OPERATING MECHANISM.

Elevators

Before fitting elevators to tail plane it is better to attach the two elevator cables, these pass through fair-leads in the rear bulkhead and then through further fair-leads attached to the front spar of the tail plane. The cables should then be pinned up to the elevator lever by means of A.G.S. pins, and finally split pinned ; next attach the elevators to tail plane rear spar, again using A.G.S. pins. $\frac{1}{4}$-in. B.S.F. bolts with slotted nuts are used for the fixing of the elevator levers.

Locking the hinge pins is accomplished by fitting a tubular collar which has a $\frac{1}{16}$-in. hole drilled ; this hole picks up with the one already in the hinge pin which is then pinned up with a $\frac{1}{16}$-in. split pin.

The control cables can now be connected up at the cockpit end. The elevator cables are attached to special links which in turn are held with special bolts.

Rudder cables are attached to the stirrups by means of $\frac{1}{4}$-in. B.S.F. bolts and slotted nuts, $\frac{1}{4}$-in. washers are used at either end of bolts.

The rudder bias cable can now be connected up, this being fixed in position by $\frac{1}{4}$-in. B.S.F. bolt slotted nut and washer.

The turnbuckles for the rudder, elevator and tail trim cables are to be found inside the fuselage aft of luggage locker. By removing inspection panel inside luggage locker the aperture will be found large enough to allow a man to pass through. It is advisable, however, before going

inside to work, to place some light form of duck-boards on the bottom of the fuselage. This will prevent damage being done to the fuselage skin; always remember to remove boards on completion of job.

When connecting up the cables, make sure that the same number of turns are given to either end of barrels.

Airspeed Patented Rudder Bias Gear (see Fig. 2.)

When rudder bias is in neutral position, not operating, slide S attached to spring is on centre line of lever A and the spring is merely pulling along the axis of lever A. Immediately it is necessary to bring it into operation, handle H is turned and slide S is moved to either right or left of lever A. This movement brings the spring into operation and when it is, say, in position shown on sketch, the spring is exerting its maximum pull on lever A which operates double lever B, through push-rod P, lever B either being the main rudder lever or/and idle lever in the system. Arrows indicate direction of actuating force.

Truing up Tail Plane and Elevators

The structure which is already in flying position should be re-checked. Set the tail plane normal to the datum, *i.e.*, the top longeron should be level. The tail plane should then be adjusted to its normal position (a special jig is used for locating this position which gives the spar centre line level) the elevators being in line with it and control column 4 degrees forward. If any adjustment is necessary, this can be made on the turn-buckles and the adjustable rod at bottom of control column.

Tail plane setting 4 degrees up and 4 degrees down.

Range of elevator angle 30 degrees up, 20 degrees down.

Range of rudder angle 29 degrees each way.

Assembling Extension

Planes

Before attempting to fit extension planes to centre section, the following items should first be given attention :—

1. See that the root-end forgings are free from all burrs and are perfectly clean.

2. Check the cones in the tapered holes to see that they bed down correctly. Up to quite recently these cones were numbered to their respective forgings, but this has now been found unnecessary, and they may now be fitted to any of the forgings.

3. Grease the forgings on main planes and centre section. It will be found that of the four main attachment bolts, two are a little longer than the other two, the longer ones being for the front spar forgings, while the shorter are for the rear forgings. With these bolts will be found eight cones and four slotted nuts, two cones are fitted to each forging.

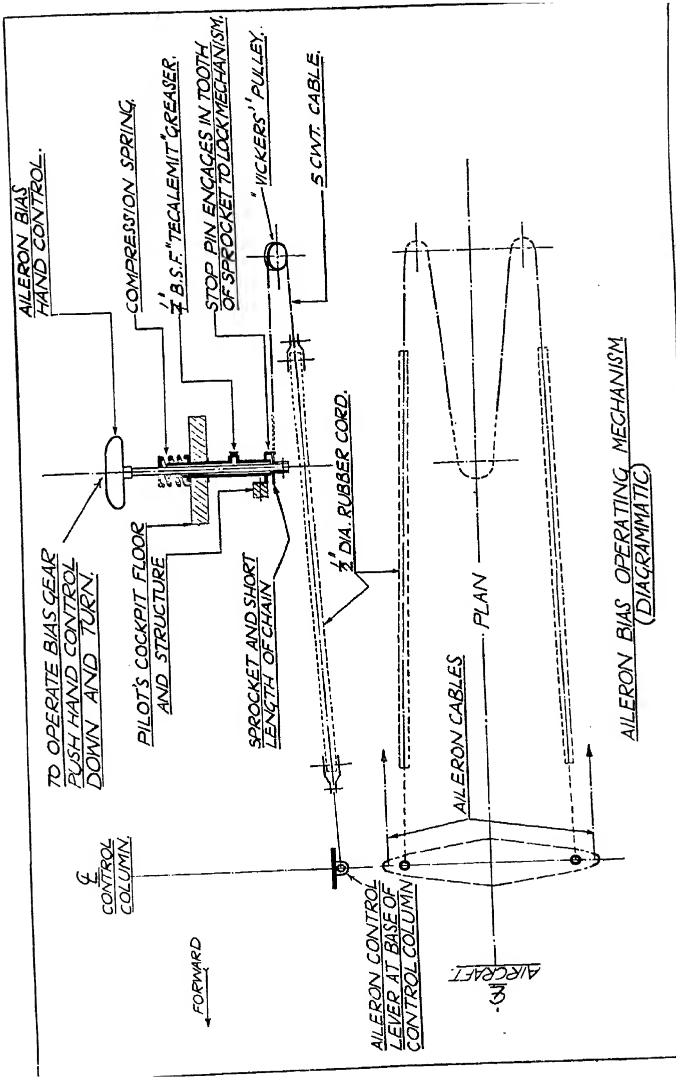


Fig. 3.—AILERON BIAS OPERATING MECHANISM.

4. Be sure to see that the bonding cords are in place, these will be found between the root-end forgings on the main plane spar.

5. Finally, make certain that the holes for aileron cables, pitot tubing and navigation lighting cables have been cut in the fabric panel which is just behind the leading edge at wing root.

The extension planes can now be placed into position, five men being needed for this operation, two at the front spar wing-root, one at the rear spar root, one at wing tip and the other to line up the holes in the forgings. The lifting of the wing into position should be taken on the spars and not by way of the leading and trailing edges.

By keeping the wing as near as possible to its dihedral angle, it will be found that the forgings will marry up quite easily.

Do not use levers to prise the wing into position, it is unnecessary and most important that they should not be used.

The top front cone should be positioned first and then the bolt, followed with bottom cone and the slotted nut. A short levered spanner should be used to tighten these nuts, it being most important that they should only be lightly tightened.

The same process should be carried out with the rear bolt. A light tap with a hide hammer on the bolts will make quite certain that the cones are seating correctly.

A trestle should be placed under the first wing fitted, this will prevent rocking of the fuselage on the tail trestle.

With the extension planes bolted in position, the aileron controls, pitot tubes and navigation light cables can be connected up, the bonding connections are to be found in the wheel bays.

To attach the ailerons to main planes, connect up the hinge-pins on top surface of aileron first, then connect up lever from sprocket wheel to its bracket on the aileron.

Care should be taken to see that the bell-cranks are at right angles to the face of the spar, which should be approximately in line with one another, and the trailing edge of aileron in line with that of the main plane.

Truing up of Ailerons

Set the control wheel to its neutral position (laterally), then adjust the turnbuckles, which are situated at the wing-root ends, until $\frac{1}{2}$ in. of droop is obtained on both ailerons. (Fig. 3.)

The range of angle of the ailerons is 26 degrees up and 18 degrees down. Main plane dihedral 5·5 degrees mean to datum. Sweepback 1·42 degrees on $\frac{1}{4}$ of chord.

On Envoy Series II the aileron controls are crossed, the balance cable picking up the outer hole in the bottom bell-crank lever and connecting up to the centre section cable, passing through top hole in fair-lead on front spar. The return cable picks up inner hole in top bell-crank

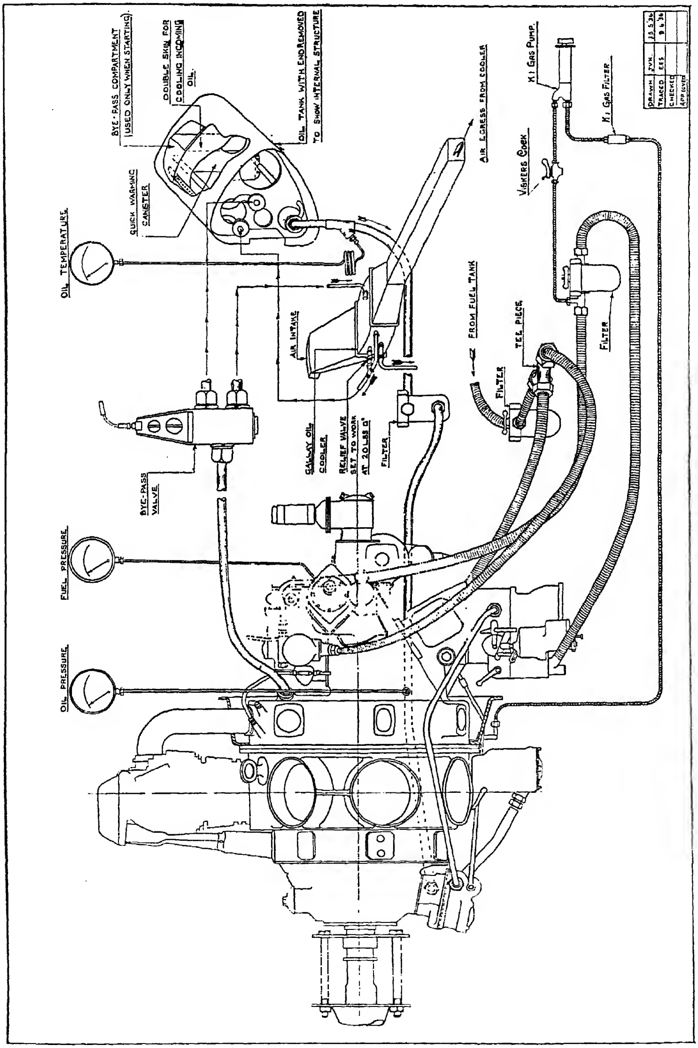


Fig. 4.—OIL AND FUEL SYSTEM COMPONENTS AND THEIR CONNECTION TO ENGINE.

lever, passing through bottom hole in the same fair-lead. The cables cross between the root and the fair-lead on No. 4 rib.

Care should be taken to see that cables are quite free in the fair-leads; there have been cases where aeroplanes have had to be left in the open during wet weather for several days, after which it was found that the controls had become so stiff that it was almost impossible to move them. This was due to the swelling of the fibre.

Make sure that the cables and swaged rods are free to travel without being in contact with each other or any part of the airframe other than their respective fair-leads.

Undercarriage

The undercarriage is of the split-axle type. The radius rod is attached to the fixed portion of the Vickers pneumatic shock-absorber leg and runs backwards to the rear spar. A pin joint divides the radius rod into two portions near the forward end. To this point is attached the hydraulic ram.

For retraction, the fluid is pumped to the lower end of the ram cylinder, forcing the piston up. As the piston rod is attached to the hinge of the radius rods, these are drawn up with the piston.

Retracting Gear

The essential units in the system are as follows :—

Control Pump

The control pump is of the double acting type, mounted below the floor-boards alongside the pilot, to his right. The pipe lines run to the ports on the valve box marked =. The internal portions of the control pump require no attention during service, as S.E.A. rings are fitted to the double acting pistons. A Tecalemit grease nipple is fitted to the hinge joint. (See Fig. 5.)

Valve Box

The valve box is mounted under the floor, immediately aft of the control pump, with the inlet side to the rear. The front and rear pipe lines from the pump are connected to the bottom and top unions respectively of the valve box as above.

The valve box consists of four connections with non-return valves, so that the top pipe line from the outlet side of the unit is always the suction line and is marked A +, the lower pipe line is always the pressure line and is marked B —. The suction line and the pressure line can now be traced to the change-over cock.

Change-over Cock

The raising and lowering of the undercarriage is controlled by the change-over cock, operating in two positions, the forward position for

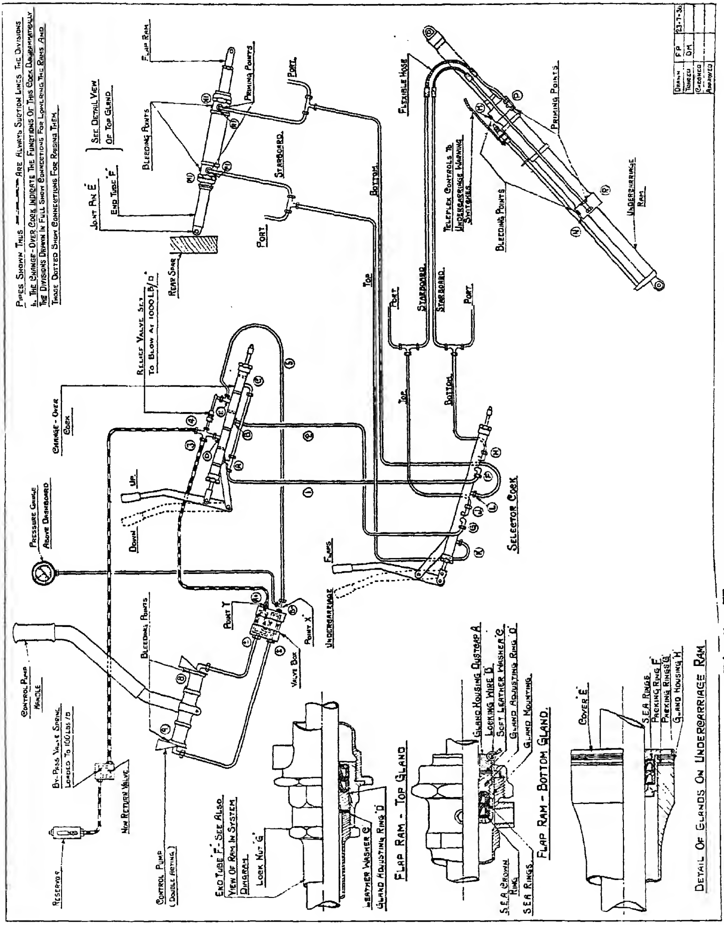


Fig. 5.—HYDRAULIC RETRACTOR AND FLAP CIRCUIT.

down and the back position for *up*. This cock is of tubular design, having five ports marked A to E (Fig. 5). Two of these ports, A and C, are connected together by a pipe. Ports A, B and E have one outlet each, marked 1, 2 and 5 respectively. Port D has two outlets, marked 3 and 4.

At ports A + and B − are situated two tee pieces, one port of each being blanked off for use as priming points. The spare connection

at A + is blanked off after priming, but that at B — is used as a coupling for the *pressure gauge* at the pilot's dashboard.

The pipes are connected as follows :—

Joint 1 runs under the cockpit floor to connection " F " on the selector cock.

Joint 2 follows the above pipe to connection " G " on the selector cock.

Joint 3 runs to port A + on the valve box.

Joint 4 runs to the non-return and by-pass valve and thence to the reservoir.

Joint 5 runs to port B — on the valve box.

Note. This description should be read in conjunction with Fig. 5.

Pressure Gauge

The pressure gauge is fitted in the cockpit, incorporated in the undercarriage warning-lamp bracket. It is coupled to the tee piece on port B — of the valve box and registers the pressure on the rams.

When the undercarriage is in the *down* position the gauge points must register between the two *red* sectors. If it stays in the lower *red* sector the hydraulic pressure is too low for safe landing. If it rises to the top *red* sector too much effort has been applied on the pump and the pressure should be released by moving the change-over cock to the *up* position and then again to the *down* position and pumping to a safe reading on the gauge.

Selector Cock

The selector cock is of similar design to the change-over cock, but has six ports. These are lettered " G " to " L " on the diagram.

Pipe lines 1 and 2 (see previous paragraph) join the cock at connections " F " and " G " respectively. Connections " K " and " L " are fitted with tee pieces, one branch of each being blanked off for priming use only. From the other branch of the tee pieces pipes run aft to the centre section, where another tee piece in each line continues the pipe to the flap rams. Connection " K " feeds the top and " L " feeds the bottom of the rams.

From connections " J " and " H " pipes are taken aft and across the aeroplane to the starboard side, then aft to the centre section where tee pieces carry branch lines to the undercarriage rams. Connection " J " feeds the top and connection " H " the bottom of the rams.

Adjusting the Flap Ram Glands

Bottom End of Ram. Reference should be made to Fig. 5 whilst reading the following instructions :—

1. Break locking wire " B."
2. Remove " gland housing dust cap " " A."

3. Remove leather washer " C."

4. Turn gland adjusting nut " D," through approximately 45° clockwise.

5. Replace " C," " B " and " A."

Top End of Ram. 1. Remove joint pin " E."

2. Slack off " lock nut " " G."

3. Remove " end tube " " F " and leather washer.

4. Carry out operation (4) as for bottom end of ram.

5. Replace leather washer " F," " G " and " E."

Hydraulic Ram

This ram should not require attention during service as S.E.A. rings are fitted to the double acting pistons. At each end of the ram there is a gland housing. (See illustration on Fig. 5 showing one end.)

Should the lower gland leak at the end of the ram, jack up the aeroplane or lash a strong wooden splint to the radius and stub radius rods to prevent the knuckle joint collapsing, take out joint pin connecting ram to radius rod, move the change-over cock to the *up* position and back again, releasing the pressure from the system. Take out the $\frac{1}{4}$-in. nuts, remove " E " and slide down piston tube, separate the first of the four $\frac{1}{32}$-in. packings " G " and remove, replace gland cover-plate and re-assemble. Take out the joint pin connecting ram to the shackle on spar, also the clips securing hose and Teleflex cable on to the top end tube of ram, put change-over cock in the *up* position and repeat the same operation on the top gland as on the bottom.

Note. Should the bottom gland require attention it is advisable to adjust the top gland also, as any leakage is hidden by the outer tube.

Important. When dismantling ends of the ram in order to remove fabric washers, do not disturb inner washer marked " F " on Fig. 5. The letters referred to are those on the appropriate Figures.

Action

When pressure is exerted in the system, the fluid under pressure is led through one or other of the main lead pipes to the hydraulic rams, so moving the pistons in the rams either *up* (if the control lever is in the back position) or *down* (if control lever is in the forward position).

Reservoir

The reservoir is mounted on the bulkhead immediately behind the instrument board. The reservoir is connected to the change-over cock on the suction side, so that in the event of leakages the correct amount of fluid is maintained in the system from the reservoir. The level of fluid in the reservoir must never drop below half. A non-return valve is placed in the pipe line leading from the reservoir.

By-pass Valve

This is placed in parallel with the non-return valve near the reservoir and limits the pressure in the return line of the system to 100 lbs. per square inch. Its action is balanced by a damping device in the reservoir.

Sizes and Dimensions of Units

Pipe lines : Tungum tube $\frac{1}{4}$ in. O/D.22G.

Flexible pipe lines : Special high pressure.

Connections : Rotherham $\frac{7}{16}$-in. O/D. 24 threads per inch. Solderless unions.

To Remove Undercarriage Retractor Rams

The aeroplane to be jacked up, leaving the wheels 2 in. clear of the ground when in the *down* position. Prior to jacking, it is always best to raise the aeroplane into approximate flying position.

Important. 1. Place the selector cock in the flap position, which will have the effect of isolating the undercarriage ram pipe line and so prevent oil being drained from the operating side of the system.

2. Remove pin connecting ram to radius rod at knuckle joint.

3. Disconnect undercarriage main pipe lines at unions at end of flexible hose on centre section spar and allow fluid to drain off.

4. Remove Teleflex control cable.

Assembly

With the aeroplane in the jacked position, proceed as follows :—

1. Connect hydraulic ram spar joint.
2. Connect hoses at centre section spar, also Teleflex control cable.

To Remove Flap Operating Rams

Important. 1. Place the *selector cock* in the undercarriage position.

2. Remove joint pins securing rams to spar and torque tube.
3. Remove Lockheed flexible hose connections at each end of rams.

Priming Flap Rams

If the rams have been dismantled for overhaul, it will be necessary to re-prime before assembling to the aeroplane.

Priming the Retractor Gear

Should it become necessary to re-prime the system, as in the case when the undercarriage has been assembled after complete dismantle, the following method should be employed :—

Use only special Lockheed oil. If unobtainable, a mixture of pure castor oil and alcohol in equal parts (by volume) may be used. No other oil is suitable and they should not be mixed.

An ordinary motor horn bulb with about 4 ft. of rubber pipe line connected to the end may be used satisfactorily during priming operations.

Priming the Hydraulic Rams

The following procedure to be followed for both rams :—

1. Remove bleeding plugs top and bottom end. Force fluid into ram through top main pipe connection, holding ram as near as possible horizontal, until pure fluid is seen to be flowing from top bleeding plug.

2. Replace top bleeding plug and close top main pipe line connection.

3. Repeat above operations with lower pipe line connection.

The hydraulic rams are now primed ready for assembly.

Priming the Systems, Flaps and Undercarriage

During these operations it must be remembered that the first principle of priming all hydraulic gear is that the fluid must be forced from the lowest point in the system to the highest point, thereby exhausting the air at the highest point. Reference to the appropriate diagram should be made when carrying out these operations. The letters used refer to those points similarly marked on the figures. In addition to the motor horn bulb, two priming cans are also required. Each can should be of about 6 pints capacity and should have a rubber pipe connection of about 4 ft. long and $\frac{1}{4}$ in. inside diameter.

Important. 1. Remove underside nose cowling. Place tail on trestle, high enough, if possible, to make the body of the undercarriage pump horizontal. This is the ideal position, but not absolutely necessary. Then jack up the aeroplane on the jacking points provided, *i.e.*, extensions of front bolts securing extension planes.

2. Take out joint pin connecting hydraulic rams to radius rod and flap rams to torque tubes.

3. Disconnect feed pipe from the reservoir at point 4 on the change-over cock and replace with a blank.

4. Place the *change-over cock* in the *down* position and the *selector cock* to undercarriage.

5. Elevate priming cans at the same level as the reservoir, take off the blanks at points X and Y on the *valve box* and attach a can at each point.

6. Fill the bulb with special oil, put bulb on the ground, take off the blank at point P on the ram, hold the bulb connection near point P and squeeze bulb until oil is forced out. Retain sufficient pressure on the bulb to keep the oil at the top of pipe and connect to point P, squeeze bulb, when oil will be forced into the can. If air is still being forced through the can when the bulb is empty, disconnect bulb, replace blank, refill the bulb and repeat the above operations until the air has been finally removed.

7. Carry out the same operation at point P on the other ram.

8. Take out bleeding plug marked M and when oil flows out replace plug. This applies to both rams,

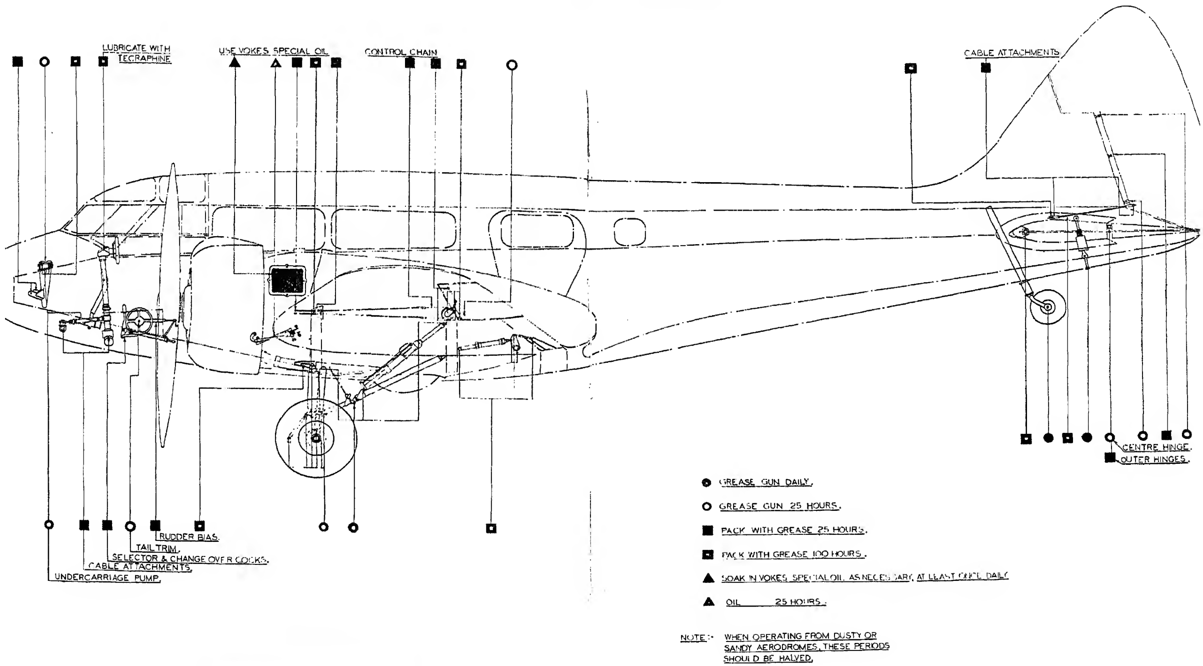


Fig. 6.—LUBRICATION DIAGRAM.

9. Carry out operation (5) at point R on the bottom of each ram.

10. When taking out bleeding plug, point N, hold the ram horizontally so as to get the bleeding point at the highest position.

11. Place the *selector cock* to "flaps."

12. Carry out operations (6), (7), (8), (9) and (10) at points P1, M1, R1 and N1 on the flap rams.

13. Disconnect cans at points X and Y and replace the blanks.

14. Fill the bulb and connect to point Y on valve box in the same way as for operation (5). Move control pump handle against the rear stop, take out rear bleeding plug on pump (8), force oil through this bleeding point until clear oil only is seen. Replace bleeding plug (8) on pump, take out the forward bleeding plug (9) and proceed as for the above. Having done this, disconnect the bulb and replace the blank. When disconnecting the bulb after having squeezed the oil into the system, it is necessary to retain a small amount of pressure on the bulb so as to prevent oil being drawn from the system.

15. Connect rams to radius rods and flap rams to torque tube.

16. Fill the reservoir and while oil is running out of the pipe, connect at point 4.

17. Place the *change-over cock* handle in the *up* position and the *selector cock* in the *flap* position.

18. Operate the control pump. If, after a few strokes, the control pump is found to be spongy, put the handle *central*, take out the rear bleeding plug (8) on the pump, move pump handle against the rear stop and replace the bleeding plug. Take out the forward bleeding plug (9), move pump handle forward until the air ceases to come out of the orifice. Replace bleeding plug, operate control pump handle; if again the pump is found to be spongy at either end, take out the bleeding plug at the end affected and carry out operation as above.

19. Operate the flaps up and down about six times. This will have the effect of dislodging air which may not have been disposed of during priming operations, and so circulate the air into the control pump, whence it can be disposed of as stated above.

20. Place the *selector cock* handle in the *undercarriage* position and the *change-over cock* in the *up* position. Operation (18) applies to undercarriage in the same way as for the flaps.

Important. Watch the reservoir and keep it full, as oil that is drained through the bleeding points is drawn from the reservoir. If the reservoir is allowed to run dry, air will be drawn into the system.

Assuming that these operations have been carried out, the aeroplane can be taken off the jacks and is now ready for use. It is of the utmost importance that operation (15) be completed before using pump, as uncontrolled movement of the ram may damage the indicator gear.

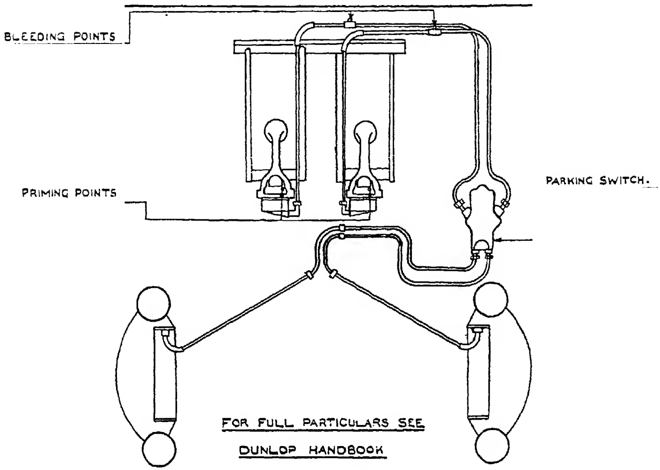


Fig. 7.—DUNLOP BRAKE SYSTEM.

Brakes

The brakes fitted are those of the Dunlop hydraulic type, and will give little or no trouble between C. of A.'s.

The following points should be noted on carrying out the installation :

1. The foot motors should be fitted in a position which will allow the pilot's toes to be just clear of the pedals when in normal flying position.
2. Make certain that sufficient length of rubber hose is used to allow the full travel of rudder pedals.
3. The brake units should be fitted on their spigots with the connections uppermost when the tail of the aeroplane is on the ground.

Priming

Jack up the aeroplane, remove the wheels and unscrew the filling valve in the top of the foot motor—about three turns in the anti-clockwise direction. A length of rubber hose is then pushed over the extending neck of the filling valve and a funnel (glass preferable) fixed at the opposite end. The funnel should be kept as high as possible. Fill the funnel with fluid, depress the pedal of the foot motor, which will allow the fluid to be admitted, release the pedal and air will be ejected: repeat this operation until all air bubbles have been removed.

The pipe line from each foot motor passes through a valve. If this valve is closed whilst the foot pedals are held hard down, the parking brake is thus obtained (Fig. 7).

Make sure after priming that the screw plug of the filling valve is well tightened.

If new brake liners are to be fitted, proceed as follows :—

1. The linings are riveted to steel plates and projections of these protrude through the housing and are held by spring pressure on clips hooked into these projections. These clips can be removed by "thumb" pressure and taken out with the springs.

2. Examination of the linings will show that on one end only of each lining the plate to which they are riveted extends for a short distance under the other shoe, the absence of rivet holes in the end of the lining indicating which is the "free" lining. Lift this free end and insert a small tommy bar across the drum. The end of the other shoe can then be withdrawn.

Vickers Oleo Pneumatic Shock Absorber Strut

This oleo strut consists of an air cylinder and a piston, the working gland between the piston and the cylinder being oil-sealed to prevent air leakage. The compressed air forms the springing medium and there is an internal oil brake and rebound damper which dissipates the energy of landing and damps out oscillations.

To re-assemble the leg, the following procedure should be carried out :—

The correct amount of P.924 oil is put into the inverted air cylinder, which may be conveniently held in a vice, care being taken not to over-tighten the vice.

The piston is now inserted and held at about half-stroke, whilst the packing rings are slipped over same and gently tapped into place by using a piece of hard wood. It is important that the rings are assembled in the correct order.

When it is necessary to add a new "U" packing ring, it should be fitted last. The gland nut is finally tightened to set the rings into place, and is then turned back from a half to one turn to allow for the swelling of the "U" rings.

The locking plate and oil valve may now be added. In some types the air valve is permanently attached to the air cylinder and requires no attention. Care should be taken that none of the measured quantity of oil is lost.

The unit may now be charged with compressed air through the air valve, either by means of a pump or from a bottle of compressed air.

The figure for the air pressure is 720 lbs. per square inch. This is usually stated on the instruction label attached to the leg.

Tail Wheel

The tail wheel unit is of the fully castoring type incorporating the principle of the Dowty shock absorber leg and relies on a coil spring and friction damping, both against rotation and up and down movement.

Maximum vertical travel is 3 in.

The only lubrication required is that of the wheel bearings.

To remove the tail wheel unit, first place a trestle under the tail which will give a ground clearance of 3 ft. from the bottom of tyre.

The tail wheel assembly is bolted to the fuselage by four bolts, the nuts being spot welded to the fitting on the inside of fuselage. By removing the locking device holding the heads of these bolts and unscrewing the bolts, the whole unit can be withdrawn.

Electrical System

This can be divided into two units, which will be described in the following order :—

I. Undercarriage warning system.
II. Lighting system.

I. Undercarriage Warning System

Attached by Teleflex cables to the hydraulic rams on the undercarriage are the operating switches for the warning horn and indicator lights which are situated behind and above the instrument board respectively. These switches are connected in parallel with each other and in series with the horn and a similar switch operated by the throttle control. Thus the warning horn sounds and the indicator lights show only when the throttle is in the shut position (or nearly so) as is the case when the pilot is preparing to land. In this case, if the undercarriage is in the *up* position the horn and the red light are on, warning the pilot to lower the undercarriage.

Removing Switches

1. Remove the cover from the two-way block which will be found on the forward face of the centre-section rear spar. Detach the two-core cable from the terminals.

2. Disconnect the switch plunger from the switch carrier on the Teleflex control by removing the two small bolts and nuts in the split connector block.

3. Remove the four fixing screws for the switch mounting and the complete unit may then be lifted off.

Note. It is not recommended that this switch should be further dismantled except by a qualified electrician. Complete replacement switches should be obtained ready for fitting.

Adjusting

1. Jack the aeroplane up securely on the jacking points provided.

When using a jack only, the front bolt each side must be used. If the trestles are used, the tail must be lifted until the aeroplane is in a

flying position and placed on a trestle. The jack is then placed under the jacking pad on the axle and the aeroplane lifted until the trestle can be inserted under the *two* bolts each side, front and rear. Insert blocks of wood (one of which should be slightly wedge-shaped) and lower the two jacking points on to these blocks, so that the load is evenly distributed. The wheel should now be clear of the ground. Then jack up the other side by repeating these operations.

2. After replacement of a new switch, switch plunger requires adjusting. Proceed as follows :—

(*a*) See that the throttle lever is back (shut).

(*b*) Pump the undercarriage to the *down* position (check cable should be taut).

(*c*) Adjust the position of the switch carrier on the Teleflex control by means of the nuts provided, so that the switch plunger just fails to make contact and sound the horn and the green light is on.

(*d*) Pump the undercarriage to the *up* position. The horn should sound immediately the undercarriage leaves the fully *down* position (*i.e.*, immediately the check cable slackens) and the light changes to the red lamp.

Horn. Type : High-frequency electric, 12 volts.

Battery. This is situated behind the pilot's seat, where it is easily accessible for " topping up " and periodical inspection.

Type : 12 volt, 25 am. hour.

Failure of Batteries and Undercarriage Warning

Should the battery or any part of the electrical circuit of the undercarriage warning device fail, the pilot is able to tell the position of the undercarriage by the pressure registered on the gauge above the warning lights.

Note. This gauge registers safe pressure, and does not indicate the undercarriage position. Always continue pumping until a maximum pressure is reached. The system is safe when the pointer lies between the two red sectors on the dial.

II. Lighting System

Dynamo

A 500 watt 12 volt " Rotax " engine-driven generator is driven from the starboard engine by a short splined coupling, and is situated on the engine mounting. Two rates of battery charging are obtainable at will by the pilot by means of switches in the main " Rotax " switchbox in the cockpit.

Dynamo Cutout

A cutout for the dynamo is fitted on the bulkhead above the main

switchbox. Should trouble be experienced with this, it should be returned to "Rotax" Service Depot.

Type: "Rotax" A.

Ignition Coils

The ignition coils are for starting purposes only, being operated by push buttons on the instrument board. Main supply is controlled by a switch on the "Rotax" switchboard and indicated by a red lamp above the push buttons.

Fuses

The following is a list of fuses, with their fusing currents, to be found in the main "Rotax" switchbox in the cockpit:—

Dashboard supply	25 amps.
Generator field	4 ,,
Cabin lights	8 ,,
Navigating lights (each)	8 ,,
Ignition boost coils	8 ,,

Fuses are in the "Rotax" switchbox on the bulkhead in the cockpit.

Landing lights (each) 15 amps. Separate fusebox.

Navigation Lights

Type: "Demec."

Lamps: 12 volts, 36 watts, double contact.

Controlled by switches in the main "Rotax" switchboard in the cockpit.

Landing Lights

Type: Vickers Armstrong.

Lamps: Phillips 12 volts, 100 watts. Single screw contact.

Controlled by a switch on the bulkhead under the main "Rotax" switchbox in the cockpit.

Inspection and General Maintenance

Inspection Covers

Below is given a list of the inspection doors and their positions:—

FOUR detachable panels, round each engine mounting.	Inspection and maintenance of engine and fuel and oil pipes.
TWO detachable panels below pilot's cockpit.	Inspection and maintenance of controls and wiring.
TWO detachable panels immediately forward of windscreen.	Inspection of instruments and rudder pedals.

ONE detachable panel in each side of centre structure below fuel tank.	Inspection of tanks and undercarriage axle fittings.
TWO sliding doors below leading edge of each main plane at root ends.	Inspection of aileron control cable joints.
TWO sliding doors on undersurface of each main plane, midway.	Inspection of aileron control levers, chains and sprocket.
ONE small door below inner hinge on each aileron.	Inspection of aileron control lever and operating arm.
ONE small door immediately behind tail wheel under fuselage.	Inspection of elevator control cables and tail trim cables and jack.
TWO hinged doors on centre section at outer ribs.	Inspection of flap rams and pipe lines.
TWELVE tear-off patches on wing and centre section top. Tie-rods may also be inspected through 18 tie-rod apertures.	Inspection of torque shaft tie-rods.

Commencing Inspection

Commence inspection of the most important points. The undercarriage and tail wheel must be inspected carefully before each day's flight and special attention must be paid to those units which receive the maximum loads.

Undercarriage

In addition to a general inspection, the following points require special attention :—

Main axle to fuselage fitting.
Top and bottom attachment of shock-absorber legs.
Brake torque rods.
Radius rod joints.
Spar fittings ; radius rod and hydraulic ram.
Hydraulic ram.
Hydraulic ram joint to radius rod.

Examine for leakage of fluid the following points, first pumping to the maximum permissible as shown on the gauge at the dashboard :—

Control pump.
Three-way cock control box and unions.
Ram pipeline joints.
Valve box joints.

Inspect the level in the reservoir daily and fill up with the special

fluid if needed. The reservoir also serves as an indicator, for if the oil level has gone down considerably since the previous inspection, it is an indication of a leak in the system. Find the leak *immediately* and rectify.

Periodically inspect the special flexible hose connections between the top of each ram and the rear spar. If they show any sign of wear or deterioration, replace at once.

The connections on the hydraulic system to be tried periodically with a spanner.

It is essential that the pressure in the oleo legs should be kept as near as possible to the maximum of 720 lbs. per square inch.

Tail Wheel and Strut

Inspect lower phosphor-bronze bearing.
Test tyre pressure.
Inspect upper attachment.
Test wheel bearings.

Brake System

Check carefully for leakage of fluid at joints.
Inspect pedal units and parking brake.

Flying Controls

Remove inspection covers where necessary.
Inspect each system individually.
Check tension of cables and movements.

(After the first few hours' flying of a new aeroplane the control cables may require tightening. This should be done without delay.)

After a Heavy Landing or Operation from Bad Ground

Examine carefully the points detailed in Undercarriage and Tail Wheel Inspection.

Examine fuselage joints. Excessive buckling of plywood or excessive unevenness indicates that opening up for further inspection is necessary.

Examine wheels and tyres.

Examine tail strut attachments.

Examine engine mountings attachment fittings.

Examine carefully wing attachment points if either of the wings has come into contact with the ground. If the fabric is torn, examine very carefully for internal damage.

Lubrication

The frequency with which the various parts of the aeroplane should be lubricated depends, of course, on the type of service on which it is operating and the common sense of the engineer. (See Fig. 6.)

Cables

The cables are coated with blue rustproof Lumilac, Specification D.T.D. 62. The only attention beyond adjustment which they require, is keeping free from dirt and oil. If required, they can be recoated with blue Lumilac or varnished, but not painted.

Fair-leads

The fibre fair-leads should not be greased. Watch for wear and chafing.

Wing Surface

Any damage to the wing surface should be repaired without delay.

See that all drainage eyelets are free from dirt and that there is no accumulation of water after washing down.

Pay particular attention to the tail plane bay of the rear fuselage.

Repairs

The maker's repair scheme for the structure of the "Envoy" is given in Volume III. of this work.

AERO-ENGINE ACCESSORIES

THE modern aero engine has tended to become more complicated as its power has increased and as its specific weight has been reduced. At the same time, it has had to cope with an ever-increasing number of accessories. These accessories are required for various purposes connected with the functioning and navigation of the aeroplane, but they are not essential to the engine as a power plant.

Taking first those components which are necessary to the engine, we find most up-to-date aero engines provided with the following :—

1. Two magnetos, incorporating automatic timing advance gear.
2. A hand- or electric-starter.
3. An engine-driven fuel pump.
4. An automatic throttle- or " boost "-control.
5. An automatic mixture control.
6. A pump for circulation of coolant, in the case of liquid-cooled engines.
7. A drive for a tachometer or engine-speed indicator.
8. A booster oil pump and/or governor for variable pitch or constant speed airscrew.
9. An engine-driven oil pump which may embody a device for providing an extra supply of oil to lubricate the cylinder walls on starting up from cold.

These accessories are usually mounted as compactly as the engine designer can accomplish on the rear cover of the engine.

Added to the problem of providing accommodation for the items listed above, the engine designer is nowadays called upon to provide drives and mountings for some, or all, of the following :—

1. Gun interrupter gear.
2. Electrical generator.
3. Air compressor for starting, brakes, etc.
4. Air compressor for automatic pilot.
5. Low-pressure air compressor for wing de-icer equipment.
6. Vacuum pump for navigation instrument operation.
7. High-pressure oil pump for operation of hydraulic retractable undercarriage mechanism, wing flaps, etc.
8. High-pressure oil pumps for hydraulically operated gun turrets.

This is truly a formidable array of accessories. It involves a great deal of work, not only in providing for the parts in such a way that the engine can easily be mounted in the restricted space provided in the aeroplane, but also in obtaining the necessary clearance testing of the drives and of the components themselves.

The photograph in Fig. 1 is a rear view of a Bristol " Pegasus " engine,

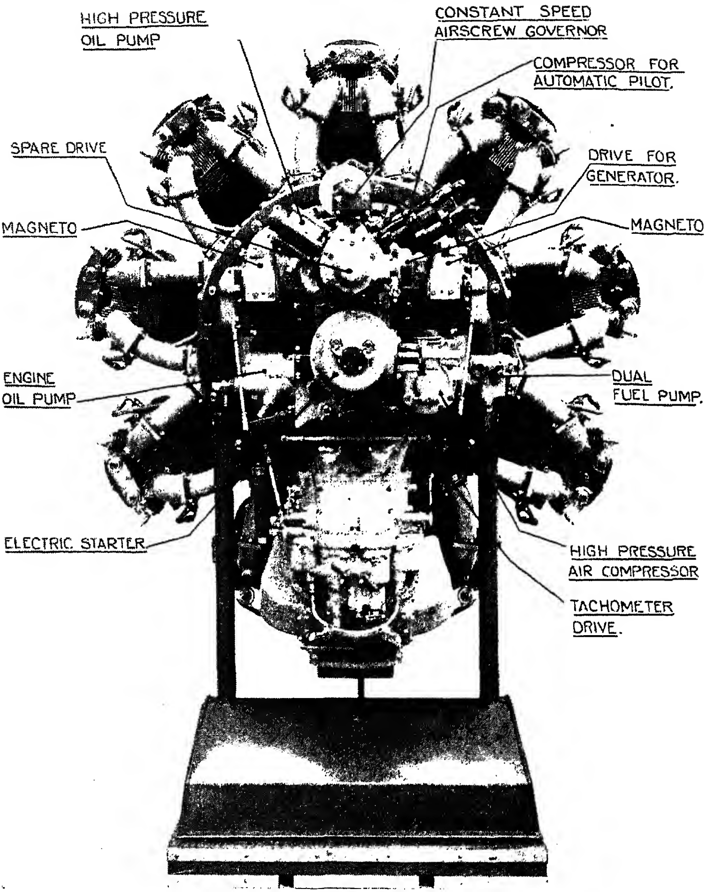


Fig. 1.—REAR VIEW OF "PEGASUS" ENGINE SHOWING ACCESSORIES.

which shows the grouping of the accessories on this particular type. On the rear cover of the engine can be seen the two magnetos, the oil pump, fuel pump, electric starter, high-pressure air compressor, drive for electric generator, low-pressure air compressor for automatic pilot, high-pressure servo oil pump for undercarriage operation, and booster pump combined with governor for constant speed airscrew. It is fortunate that the

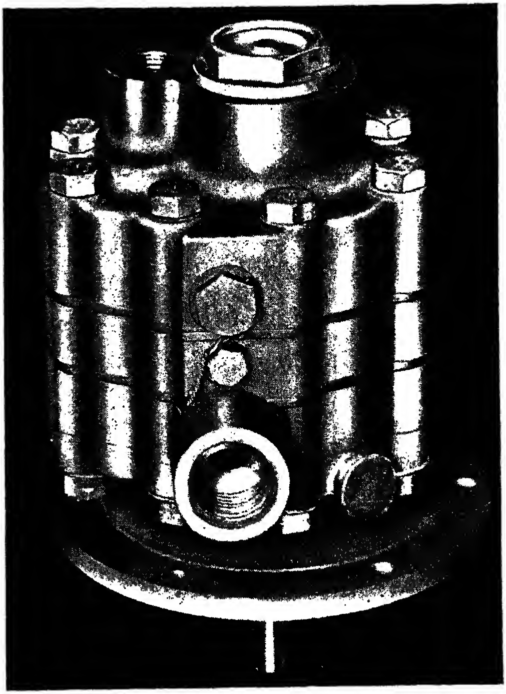


Fig. 2.—B.H. ENGINE-DRIVEN PUMP.

majority of aeroplanes carrying both retractable undercarriage and gun turrets have more than one engine, so that it is possible to share out the hydraulic power units amongst the engines.

As those accessories which are essential to the operation of the engine are dealt with in detailed descriptions of the different types of engine, it is proposed to devote this article to a description of the various components which the engine is called upon to drive for other aeroplane services.

There has, during the past two or three years, been a very intensive development of engine-driven accessories to keep pace with the demands of the aeroplane designer for more and more services to reduce the effort required by the pilot. More particularly has this been the case with hydraulic servo power. Until recently such operations as raising the undercarriage, moving the wing flaps and rotating the gun turrets were effected manually by the pilot or his crew. Now high-pressure oil is used to an increasing extent, although it is still customary to provide emergency manual operation.

It is in this branch of hydraulic services that progress has been most rapid, and as this development has entailed the solving of many interesting problems it is proposed to deal with these accessories first.

HYDRAULIC PUMPS

Table I gives particulars of typical pumps which are available at the present time. The list cannot, however, be regarded as complete, as new

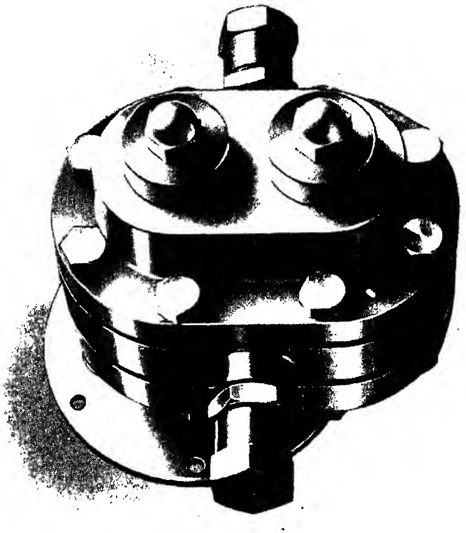


Fig. 3.—DOWTY ENGINE-DRIVEN POWER PUMP.

types are being developed almost daily. It will be seen that there is rather a wide variation of sizes and pressures, but it is hoped that as more experience is gained in actual service pressures and outputs will become standardised.

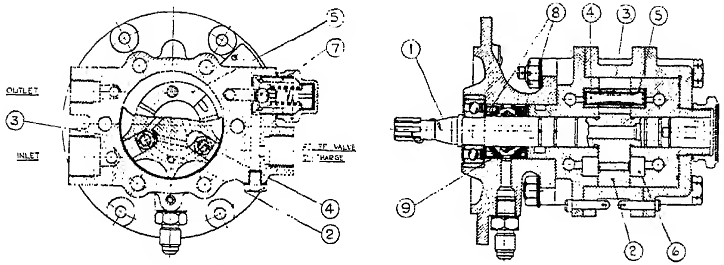
Servo pumps for aeroplanes present special problems in view of the high pressures required and the great restrictions on weight and size. Moreover, as the working fluid is used to transmit energy to exposed parts of aeroplane, it is essential that its freezing point must be low. Accordingly the fluids usually adopted are specially compounded with this object in view, and in common use are gun oil (Specification DTD.44.B) and fluids similar to those used for hydraulic brakes, but having a still lower pour point. These last usually contain alcohol. It is most unfortunate that all of the fluids used have very poor lubricating properties.

The types of oil pump available are as varied as the makes, nearly every manufacturer having adopted a different mechanism which has some particular advantage from the point of view of compactness, lightness or high efficiency. This variety of types makes the study of these pumps very interesting.

We will deal first with the pumps which have been developed in this country.

The B.H. Engine-driven Pump

Fig. 2 shows this pump, which is of the gear type, but which is unusual in that it has three stages in series. Thus each stage of the pump only generates one-third of the total pressure delivered, so that a high efficiency is obtained. The pump has been tested at speeds up to 3,500 r.p.m., while it will deliver at full pressure at speeds as low as 400 r.p.m. It has



ig. 4.—LOCKHEED ENGINE-DRIVEN FLUID PUMP. MARK IV MODEL.

been subjected to very lengthy and comprehensive testing, with marked freedom from wear, which is shown by the way in which the output is maintained after long periods of running.

Other pumps of this type having a higher delivery at a lower pressure are being developed for use with gun turrets. Twin pumps are also being made which comprise one low-pressure gun-turret pump and one high-pressure under-carriage pump in one integral casing, with a single drive. Thus one engine drive only is needed and the problem of accommodation on the engine is simplified.

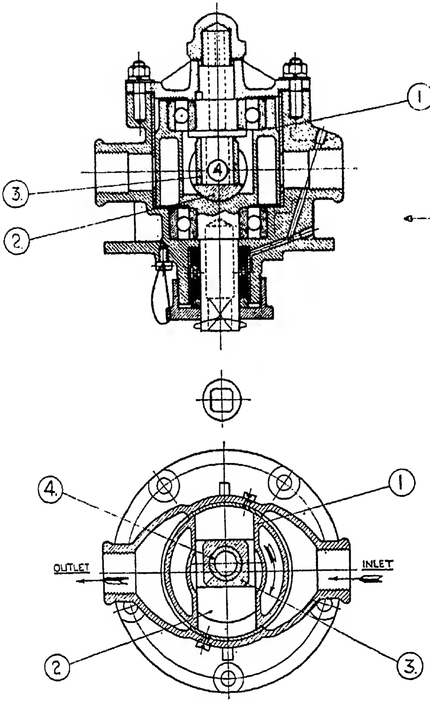
The Dowty Engine-driven Power Pump

This pump has been designed to give a high-pressure supply of oil for undercarriage and flap operation, together with a high delivery for the gun turrets. The photograph in Fig. 3 shows the pump, which is extremely simple in design, consisting as it does of a single stage of gears. Special precautions have been taken to overcome the inherent faults of this type. For instance, working clearances have been kept small in order to maintain high output at low speed, and a special aluminium alloy has been employed for the casing in order to prevent undue increase of these clearances with rise of temperature. The pump is robust and has behaved very well in service. Increased capacities can very easily be obtained simply by increasing the face width of the gears.

The Lockheed Engine-driven Fluid Pump

There are three models of this type at present being produced, all employing the same principle. The diagram in Fig. 4 shows the Mark IV model.

Referring to the diagram, the driving shaft (1) is integral with a rotor head (2) in which three equally spaced radial slots are cut. These slots transmit the drive through rollers (3) to pins (4) which are attached to the three segments (5). These segments are constrained to rotate in an annular groove (6) which is eccentrically disposed to the driving shaft. This offset of the segments causes them to travel at varying circum-



ig. 5.—ROTOPLUNGE HIGH-PRESSURE OIL PUMP.

ferential speeds depending upon the speed of the rotor and the effective radius from the centre of the driving shaft.

Ports are cut in the annular groove, and are arranged so that while the distance between any two segments is increasing they are travelling over an inlet port and while the distance is decreasing they are passing over a delivery port.

The delivery port is also in communication with a spring-loaded ball relief valve (7) which blows off at a pressure of 1,400 lbs./sq. in. into a relief line which passes the fluid back to the supply tank.

Close to the splined end of the driving shaft are two gland seals (8), between which is an oil thrower (9). Any working fluid which passes the inner gland or any engine oil which passes the outer one is thrown back and can be drained to any convenient point on the aeroplane.

The pumps depend for their efficient working upon the very fine tolerances maintained in the working parts. Moreover, such is the quality of manufacture and of the materials employed that after 500 hours' running under load the drop in performance is less than 10 per cent. Since the pump will only be under load occasionally in flight the 500-hour period represents a very much greater flying time.

The Mark V pump has a rated delivery of 150 cu. in. per minute at about 1,250 r.p.m. It has three segments. The Mark IV pump has double the delivery, with three segments at each side of the rotor. The Mark III pump has two independent deliveries, each of 150 cu. in. per minute. It is also provided with two independent relief valves.

These pumps are designed to operate on Lockheed special aircraft

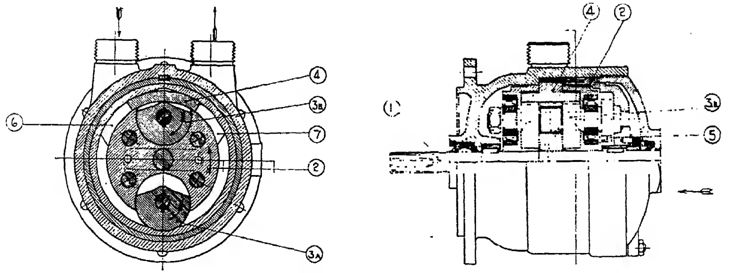


Fig. 6.—TECALEMIT HIGH-PRESSURE OIL PUMP.

fluid which has been developed in conjunction with the rubber glands employed in all Lockheed systems. The fluid has satisfactory properties between temperatures of 140° C. and −50° C. Special Lockheed rubber hoses are used, and in order to obtain maximum life the temperature at the pump must not exceed 65° C.

The Rotoplunge High-pressure Oil Pump

This pump is illustrated diagrammatically in Fig. 5. It is of the plunger type, but oscillation of the plunger is effected in a unique manner. The rotor (1), which is recessed for lightness, is integral with the driving shaft, which takes its drive from the engine through a square hole, engaging with the square end of a quill shaft. The steel plunger (2) is circular in section, with ends rounded to conform with the pump casing liner bore. Midway along its length the plunger is gashed to receive a square bronze block (3), which is mounted on a pin (4) fixed eccentrically in the pump cover.

As the driving spindle rotates the plunger is caused to oscillate in the rotor. The stroke of the plunger is dependent upon the offset of the fixed pin.

The rotor is mounted on ball bearings, the lower one being carried in the casing, the upper one being fixed in the rotor and carried on the fixed pin.

The Tecalemit High-pressure Oil Pump

This is a recently developed pump of unique design, which possesses many properties which may prove to be of great value.

The mechanism, which is shown in the diagram in Fig. 6, can be applied equally well to a pump or a motor, and with oil, water, fuel or air as the working medium. Its efficiency at high outputs is claimed to be very high, and this is due largely to the effective seals and to the fact that no parts of the mechanism, with the exception of the bearings, are in frictional contact.

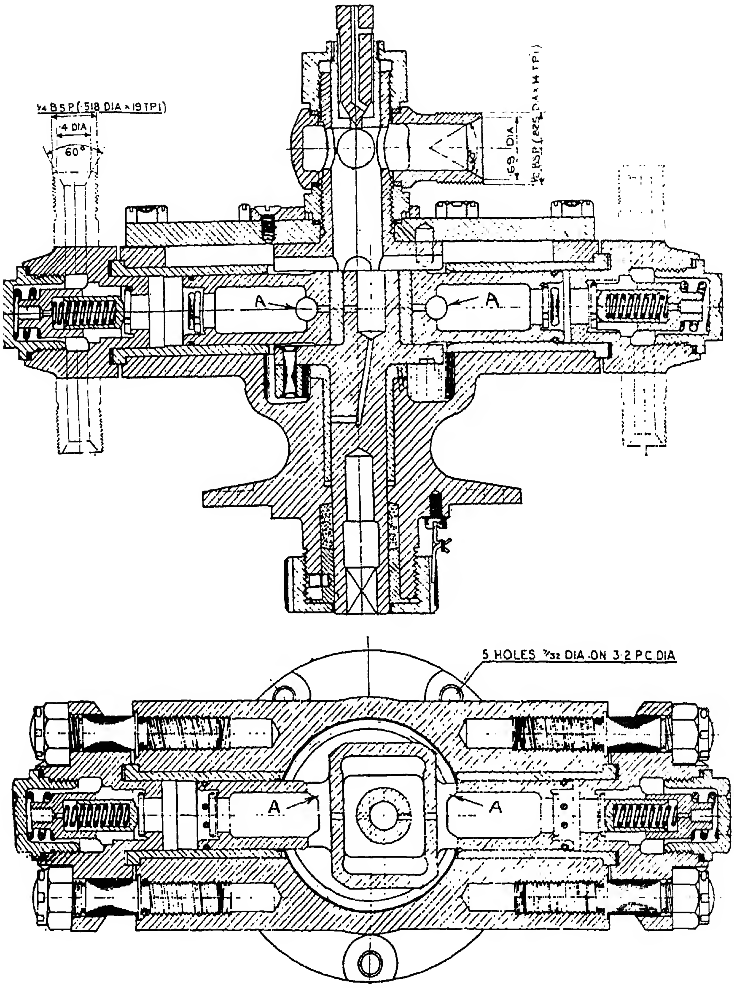


Fig. 7A.—VICKERS HIGH-PRESSURE OIL PUMP.

Referring to the diagram, the driving shaft (1) carries a rotor (2) having two recesses for the blades (3a) and (3b) and a circular groove machined in its face. In this groove is a fixed abutment (4) which comes

between the inlet and outlet ports. The blades (3, a and b) are mounted on spindles integral with gears (5), which are in train with a gear mounted on the rotor. The shape of the blades and the ratio of the gears are such that the blades are revolved to come completely into their recesses when passing the abutment. In the outer portion of the recess in the rotor are machined circular recesses so that at the appropriate times the blades make area seal instead of the usual line contact.

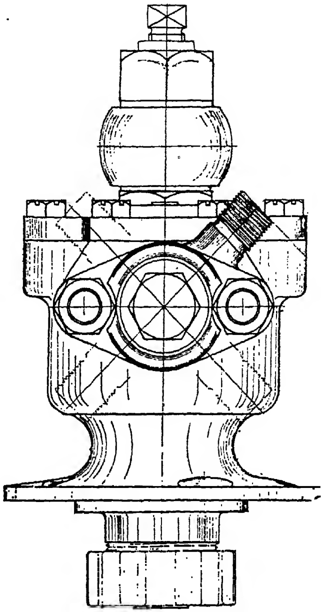


Fig. 7B.—VICKERS HIGH-PRESSURE OIL PUMP.

Operation may take place in either direction, but if we assume the direction of rotation shown, then (6) will be the inlet port. Fluid is being drawn into the groove in the rotor until both blades are making area seal when it is trapped between the two blades. Blade (3a) breaks seal when it reaches the outlet port (7) and blade (3b) forces the fluid through this port, while at the same time drawing in more fluid for the next operation. The action is continuous, without pulsation of any kind.

In actual practice the rotor carries blades on either side, as shown in the longitudinal cross section, so that end thrusts are eliminated. Furthermore, the loads on the blade when it is under pressure are disposed on either side of the axis so that they are almost completely balanced.

Another pump of this type is being developed in which there are two fixed abutments and four blades, with two independent inlet and outlet ports. Thus two separate services can be operated from the one pump, and, moreover, due to the arrangement of the blades, each delivery is approximately the same as that of the pump just described, although its size is very little greater.

The Vickers High-pressure Oil Pump

In marked contrast to the pump just described, this one is designed on very orthodox lines. It has been developed specifically for the operation of such things as retractable undercarriages, landing flaps and bomb door mechanism.

As will be seen from Fig. 7, the pump is of the plunger type, with two

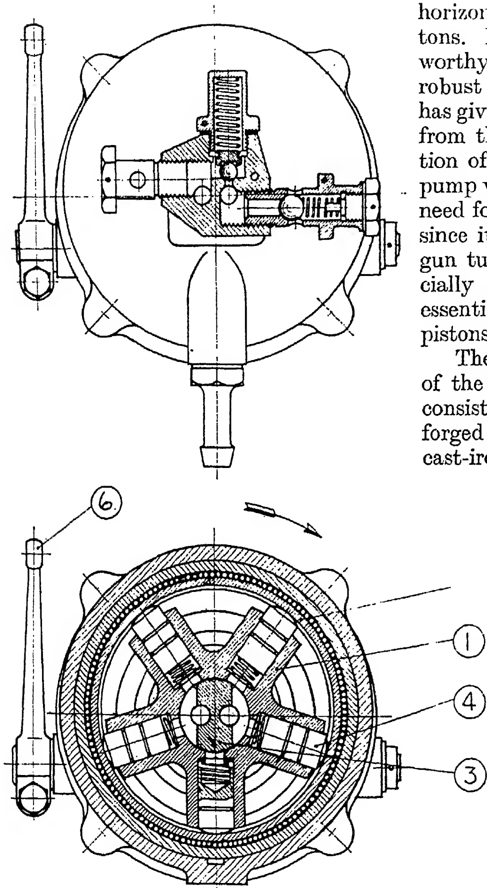


Fig. 8A.—MESSIER (A.B.) HYDRAULIC PUMP. TYPE P.O.

horizontally opposed pistons. It is particularly noteworthy for its simple and robust construction, which has given trouble-free service from the outset. The adoption of the plunger type of pump was determined by the need for high pressures, and since it was not required for gun turrets, where an especially smooth delivery is essential, the use of only two pistons was permissible.

The general construction of the pump is very simple, consisting as it does of a forged duralumin body with cast-iron cylinder liners. The opposed pistons are of air-hardening steel, and are made integrally with the cross-head. They are lapped into the cylinders and carry inertia-controlled disc-type suction valves in their outer extremities. One-hundred-ton air-hardening steel is used for the crankshaft, which runs in bearings of phosphor bronze. Partial balance is obtained by means of a counterweight riveted to the crank disc. Gun oil (DTD.44.B) enters the crank chamber through the banjo connection in the cover plate and passes into the pistons *viâ* holes " A " and through the disc valves into the cylinders, on the inward stroke. The outward stroke delivers the oil through the spring-loaded disc-type discharge valves. There are two separate deliveries which are interconnected by means of an external pipe.

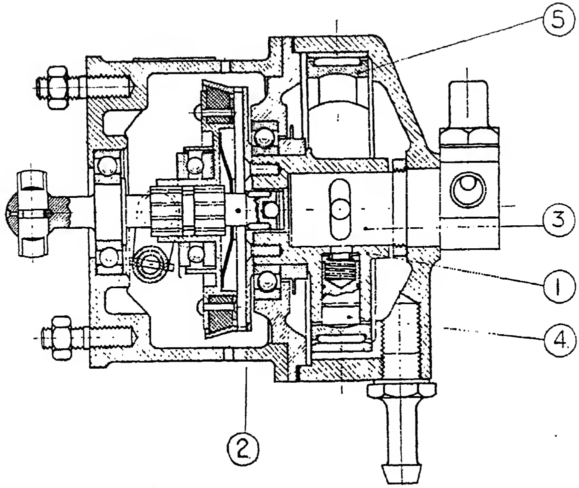


Fig. 8B.—MESSIER (A.B.) HYDRAULIC PUMP. TYPE P.O.

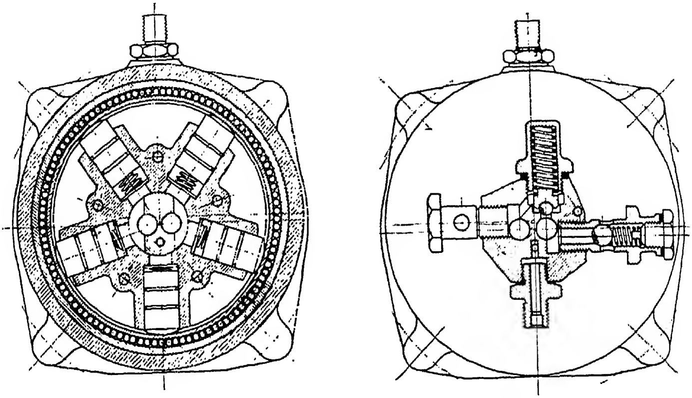
The working fluid is used to lubricate the shaft bearing and egress from this bearing is prevented by means of a substantial gland. This pump may be run up to a maximum speed of 1,500 r.p.m.

The Messier (A.B.) Hydraulic Pumps

These interesting pumps of French origin are unique in having means whereby they can be completely disconnected from the engine when not required.

The A.B. pumps operate at normal engine speeds and are capable of producing pressures up to 1,400 lbs./sq. in. As is usual when such high pressures are involved, the pumps are of the plunger type.

As will be seen from the diagram in Fig. 8, the pump rotor (1) is a block comprising five cylinders fixed rigidly to the female member (2) of a cone clutch. The cylinder block rotates concentrically around a stationary cylindrical distributor (3) which contains the oil inlet and delivery ports. The five cylinders carry pistons (4) which bear against the hardened steel race (5), which is mounted on needle roller bearings in the pump casing and which is disposed eccentrically with regard to the rotor. Each piston has thus a stroke equal to twice the eccentricity, and one stroke is executed during each half-revolution of the rotor. The distributor has two openings, corresponding to the induction and discharge strokes. These openings communicate with pipe connections on the outside of the pump.



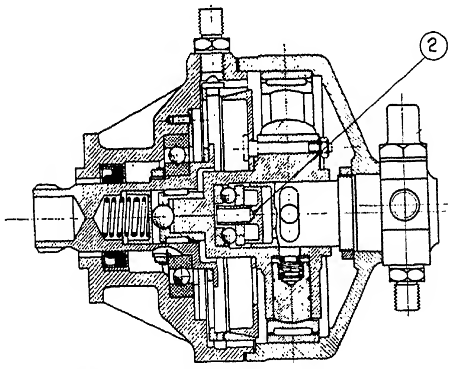


Fig. 9.—MESSIER (A.B.) HYDRAULIC PUMP. TYPE P.43.M.

When the pump is used only for high speed operation, the centrifugal force on the pistons is sufficient to keep them in contact with the eccentric track, but when pressure is required at low speeds springs are necessary to maintain this contact. A simple spring-loaded ball safety valve is provided at the outlet to return the oil to the inlet side if the pressure exceeds the maximum value.

All A.B. pumps are provided with a cone clutch to enable the pump to be disconnected from the engine. In the case of the P.10, P.12 and P.13 models, the male member is splined to the driving shaft and is operated manually by the pilot by means of lever (6). The driving shaft is ball-ended and has a tongue for engagement with a special articulated cardan shaft, an arrangement permitting the pump to be mounted on the bulkhead.

Type 43M, a cross-section of which is shown in Fig. 9, is a more recent model. Here the rotor is fixed to the male member of the clutch, while the female member is splined to the driving shaft, which in this case is

splined at its outer end, for direct mounting on the engine. The clutch is engaged by means of the small piston (2) located in the distributor. Compressed air is led to this piston and moves the whole cylinder block, and with it the male clutch member, engaging the clutch.

These pumps, being valveless, are capable of rotation at speeds of over 3,000 r.p.m. By maintaining fine clearances between pistons and cylinders it is possible to obtain pressures as high as 2,000 lbs./sq. in. using special thin anti-freezing fluid.

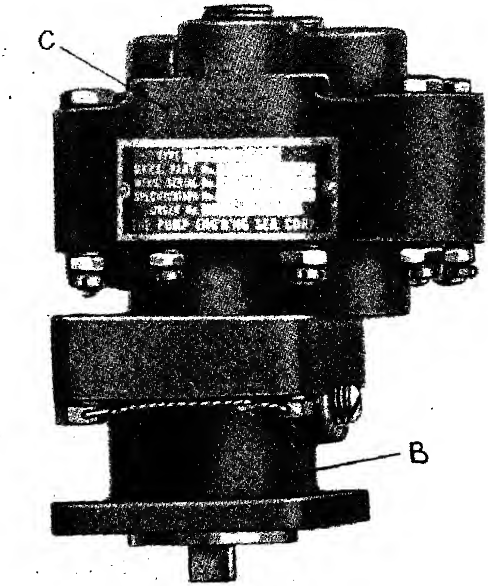


Fig. 10.—PESCO HIGH-PRESSURE OIL PUMP.

By reason of the high speeds and pressures attained, the pumps are small and light for their output. They are used extensively on the Continent.

The Pesco High-pressure Oil Pumps

These pumps, and also the next ones to be described, are of American origin.

Reference to Table I shows that there is a very wide range of pumps of this make covering outputs of from 60 to 500 gallons per hour and pressures from 200 to 1,000 lbs./sq. in. The pumps are of the spur gear type, and they incorporate several notable features.

In Fig. 10 is a photograph of a typical member of the series. It incorporates two spur gears machined integrally with their shafts, which are supported in very sturdy plain bearings. In order to maintain close clearances on the end faces the end cover " C " is provided with a gasket, the thickness of which may be varied, thus enabling the efficiency of the pump to be kept up.

The driving shaft is separated from the driving gear, with which it

Fig. 11.—ROTAX-ECLIPSE HYDRAULIC PUMP.

engages by means of a tongue and groove coupling, so that in the event of the pump seizing through any cause, with consequent failure of the shaft, replacement can be made at a minimum of cost. Another important advantage lies in the added flexibility of design, as it is a simple matter to change the shaft for one having another type of coupling to suit any particular engine. This driving shaft is carried in a plain bearing of generous proportions; it is provided with a specially developed metallic oil seal which has been found to be extremely efficient in preventing leakage of the working fluid into the engine. The mounting base "B" is separated from the main casting so that the pump may be readily adapted to any desired type of mounting flange.

For a gear pump it is remarkably efficient, and this high performance has been obtained by holding manufacturing tolerances to very close limits, and by adopting special alloys for the pump casing and liners, so that clearances remain sensibly constant throughout the range of working temperatures. The pump may be driven in either direction.

The Rotax-Eclipse Hydraulic Pump

These high-pressure oil pumps are extremely simple in conception and design, embodying as they do the patented "Gerotor" principle, which consists essentially of a positive displacement internal rotary movement.

In the pump shown in Fig. 11 there are only two moving parts, the rotor, which carries internal teeth of special form, and the driving gear, which is a spur gear having one tooth less than the rotor. It is in effect a gear pump having an internal gear instead of two spur gears.

The gears are overhung from a sturdy two-row ball bearing, the driving shaft incorporating a flexible coupling and a shear pin which is designed to break in case of failure of the pump. In this way the engine driving gears are safeguarded. The pump is capable of being driven in either direction, and in emergency pressures in excess of 1,000 lbs./sq. in. may be attained.

There are models designed to be driven by the engine at a normal speed of one and a half times that of the crankshaft, and a model for electric motor drive, forming a self-contained unit.

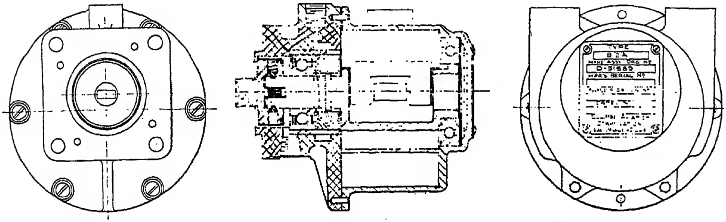


Fig. 12.—ROTAX ECLIPSE VACUUM INSTRUMENT PUMP.

VACUUM PUMPS

Many aeroplane navigating instruments, including the turn-and-bank indicator, directional gyro, artificial horizon and "robot" pilot, are operated by suction. This suction was originally obtained from venturi tubes placed in the slip stream, but this means has been found very unreliable owing to the danger of the tubes becoming clogged with ice and snow.

Probably because flying is carried out in more difficult weather conditions in the United States of America, it is there that the need was first felt for a more reliable alternative and so we find that all the vacuum pumps available in this country originated in the United States.

These vacuum pumps are engine driven; they operate by drawing air through the instruments. Means are adopted to ensure a constant suction from low engine speeds upwards, so that the instruments are available at all normal flying speeds. In addition, the exhaust air can be used to operate wing de-icers.

The Eclipse Vacuum Instrument Pumps

These pumps are of the rotary sliding-vane type, having two vanes which cross each other to give four effective surfaces. As will be seen from Fig. 12, the rotor is carried on ball bearings, so that friction is reduced to a minimum.

Positive lubrication is effected by means of an integral oil-metering device which is adjustable within extremely close limits, so that the quantity of oil entering the pump can be controlled. This ensures that an adequate supply of oil is maintained to provide correct lubrication of the working parts, and at the same time to seal the vanes where they contact the pump body, thus keeping the efficiency of the pump at a maximum. On the other hand, the quantity of oil is not allowed to be so great that the interior of the pump becomes flooded and there is risk of depleting the engine supply.

The oil is taken from the main engine pressure system and can usually be led into the pump either by an external pipe line or through passages in the mounting face.

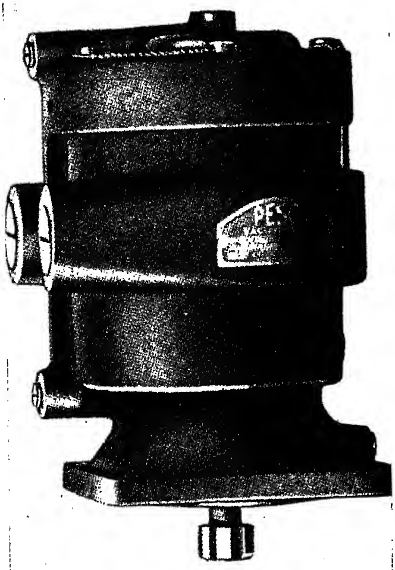


Fig. 13.—PESCO VACUUM PUMP.

Alternative driving shafts and flanges are provided so that the pumps may be applied to various makes of aero engine.

Since it is necessary to maintain sufficient suction to operate the instruments at low engine speeds, the suction at normal engine speeds is in excess of instrument requirements and it is necessary to install in the system a suction regulating valve. The Eclipse valve has four connections, for use with the different instruments.

The Pesco Vacuum Pumps

The vacuum pumps in this range may be represented by the model shown in Fig. 13.

This pump is of the rotary vane type, with four separate sliding vanes carried in a rotor and supported on a floating hollow spindle. The vanes are made of nitrided steel, as is also the pump liner, so that wear is not measurable after considerable periods of running.

The rotor is mounted on ball bearings and lubrication is effected by means of oil taken from the engine pressure system. This oil may be led into the pump either through holes in the mounting pad face or by external pipe line to alternative connections at the upper or lower end of the pump. It then passes through internal ducts to a fixed metering plug in the upper end cover.

As in the hydraulic pumps of the same make, the driving shaft and mounting flange are both separate, so that the pump can readily be adapted to any desired mounting pad and drive.

In view of the relatively large inertia of the rotating parts, it is thought advisable to interpose a leaf spring between the driving shaft and the rotor.

In addition to providing a high suction for instrument operation, the pumps are capable at the same time of providing pressure air at the exhaust side for inflation of the Goodrich wing de-icer. When this is done and also in most cases when the air is exhausted directly into the atmosphere, it is advisable to pass the air through an oil separator, which

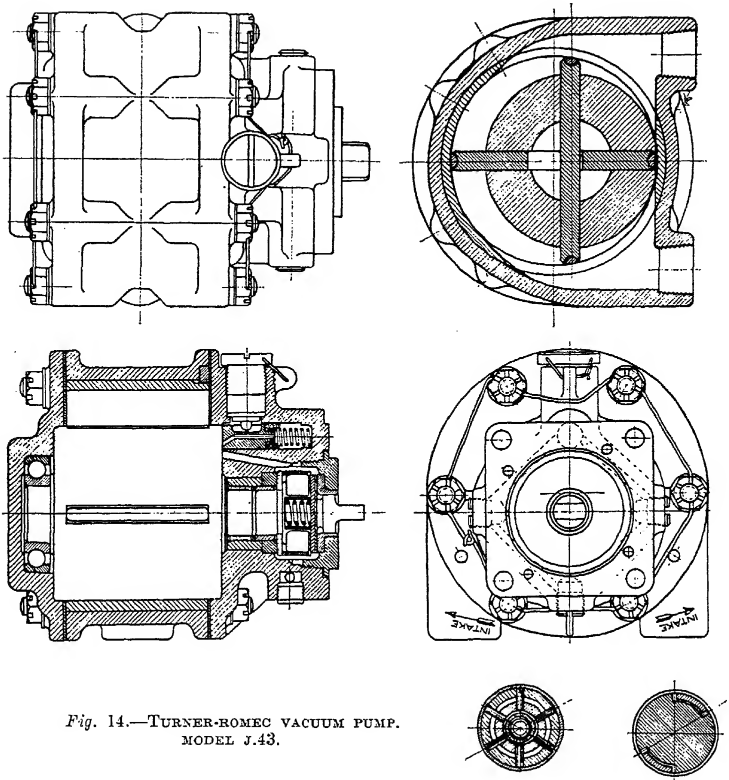


Fig. 14.—TURNER-ROMEC VACUUM PUMP. MODEL J.43.

consists simply of a small tank with suitable internal baffles and a drain to take the oil which is collected into the crankcase or preferably into the oil tank.

The Turner-Romec Vacuum Pumps

These pumps are manufactured in a range of sizes and are designed for the operation of vacuum instruments such as the turn-and-bank indicator, the directional gyro and the artificial horizon.

They are rotary vane pumps, and the model J.43 shown in section in Fig. 14 employs two solid sliding vanes contacting with the pump liner through slippers. The bore of this liner follows a limacon curve so that

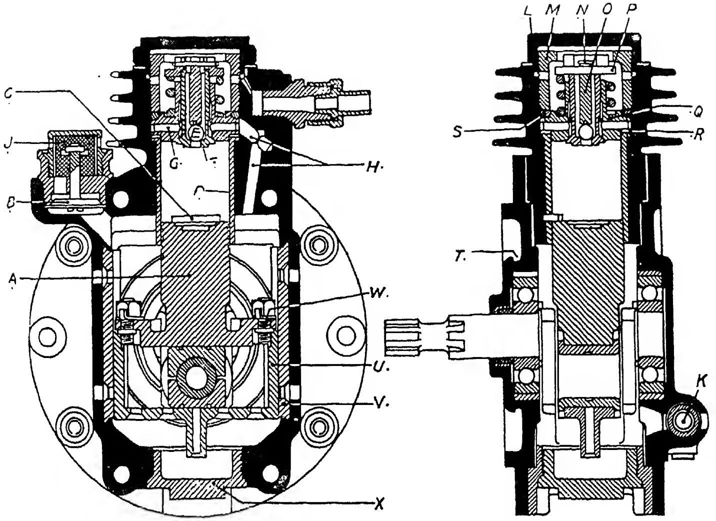


Fig. 15.—B.T.H. AIR COMPRESSOR. TYPE A.V.

full contact is maintained in all positions without the use of divided vanes and springs.

The hollow rotor is carried on a ball bearing at its outer end while a grooved sturt at the driving end is located in the specially extended inner race of a needle roller bearing. Drive is effected by means of a tongued coupling which engages through a leaf-spring drive with a second tongued coupling meshing with the groove in the extension of the rotor. The pump can be driven in either direction, and it is usually mounted directly on the engine.

An interesting system of lubrication is employed. Oil enters either through one of the four holes in the face of the mounting pad or through an external pipe line connected to one of four inlets immediately above the mounting flange. It then passes through the oil restrictor, which is spring loaded to maintain contact with the lower face of the rotor. This restrictor has a sealing washer at its lower end to ensure that oil reaches the moving parts only by way of the metering hole. Oil is thus led to the lower face of the rotor whence by rotation and suction it is distributed throughout the pump. A duct passing from the lower face of the rotor to the spring drive chamber leads oil to lubricate this coupling.

When necessary an oil separator is placed in the exhaust pipe line to reclaim oil which is led back into the engine system. A separate relief valve is supplied ; this is incorporated in the pipe line.

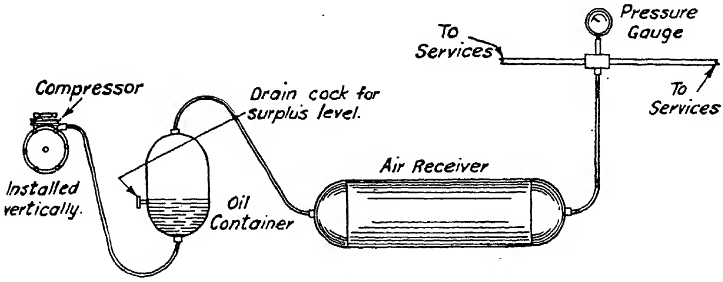


Fig. 16.—B.T.H. AIR COMPRESSOR. INSTALLATION.

AIR COMPRESSORS

High-pressure air for use on aeroplanes is usually at a pressure of about 200 lbs./sq. in. It has been applied to engine starting, operation of air- and wheel-brakes and sirens, but is not used nowadays for starting nearly so extensively as it was, being replaced very largely by inertia- or electric-starters.

Usually the compressed air is obtained from an engine-driven compressor which is used to charge an air bottle, but in the absence of such a compressor the bottle may be charged on the ground, although this is obviously a restriction on its use.

The B.T.H. Lightweight Compressors

These are the only high-pressure air compressors used in this country, although there are one or two other types in use on the Continent. There are two types, both being single-stage reciprocating compressors, one with a single cylinder and the other with two. The compressors are very small, as will be seen from the photograph of the engine in Fig. 1. They are driven continuously and maintain a constant pressure in the air bottle. When the maximum pressure is attained in the bottle the compressor cuts out and idles until the pressure falls.

The type A.V. compressor has one cylinder, and it is shown diagrammatically in Fig. 15. It has a piston displacement of 0·368 cu. ft. of free air per minute at a speed of 1,200 r.p.m.; it is designed to charge an air bottle of 400 cu. in. capacity to 200 lbs./sq. in. from atmospheric pressure in ten minutes. At 200 lbs./sq. in. discharge pressure it absorbs 0·175 horse power; its weight is $4\frac{1}{2}$ lb.

The type A.W. compressor has two cylinders and double the output and weight of the A.V. compressor.

Referring to Fig. 15, it will be seen that the compressor consists of a single piston "A," driven by means of a crankshaft and integral crosshead "V." On the upward stroke of the piston air is drawn into the crankcase

Fig. 17.—" BRISTOL " GUN-FIRE CONTROL GEAR WITH AUTOMATIC ADVANCE.

through the automatic inlet valve "B." As the piston descends the air in the crank-case is compressed; at the lower end of its stroke the piston uncovers a port " C " in the cylinder wall " D " and the air enters and fills the cylinder. On the next upward stroke the air in the cylinder, after having been compressed still further, passes through the ball valve " E " into the air receiver.

When the air in the receiver attains the pressure for which the spring loaded relief valve " F " is set, the back pressure from the air bottle, acting upon this valve, causes it to open, so that the air from the cylinder is by-passed directly through passages " G " and " H " back into the crankcase.

In these circumstances no further pressure is generated and the air is simply circulated through the crankcase and cylinder.

The complete installation, which is shown in Fig. 16, consists of the compressor, an oil container of 1½ pints' capacity which contains ½ pint of engine oil to specification DTD.109 and the air receiver. The function of the oil container is important. When the compressor is pumping, the air passes through the oil into the receiver. When the compressor cuts out, the back pressure from the air bottle forces oil back along the delivery pipe to the compressor head and seals the ball valve " E."

The very small size of the piston precludes the use of piston rings, and a seal is obtained by maintaining in the crankcase a level of oil. The sump holds approximately 20 c.c. of oil; it is necessary to check and to maintain the level by pouring in oil through the inlet valve after every ten hours' running.

The compressor is air-cooled and on installing it care must be taken to ensure that the temperature of the cylinder head does not exceed 70° C.

GUN-FIRE CONTROL GEAR

Although with the general adoption of twin-engined aeroplanes the practice of mounting machine guns to fire through the airscrew disc is being dropped, there are still some single-engined aeroplanes where gun-interrupter gear is necessary.

The purpose of this gear is to control the firing mechanism of the gun so that bullets will pass between the blades of the airscrew and not through them.

In essentials the generator for the Constantinesco gun gear, which is used in this country, comprises a plunger which reciprocates in a housing mounted on the engine and imparts its motion through a column of oil to the trigger-actuating mechanism at the gun. The plungers are operated by means of cams rotated at airscrew speed by the engine. Now an appreciable period of time elapses between the arrival of the cam at the generator and the passage of the bullet through the airscrew disc, so that the cam must be advanced by an amount depending on the length of pipe line and the distance from the nozzle of the gun to the airscrew. Moreover, this time interval is sensibly constant, whereas the time taken for an airscrew blade to traverse a given angle will vary with engine speed. Over the permissible range of engine speeds, therefore, there will be a spread of bullets and it is necessary to check cam timing and operation on a given installation by firing through a wooden disc bolted to the airscrew hub.

When two-bladed airscrews are used the angular distance between the trailing edge of one blade and the leading edge of the next is sufficient to cover the spread over the full speed range of the engine, but when three or four blades are used the permissible speed range must be limited.

In order to overcome this limitation the Bristol Aeroplane Company has developed a gun gear drive incorporating an automatic cam advance. In this unit, which is shown in Fig. 17, the cams are mounted on a shaft which is rotated by the action of governor weights so that as the engine speed increases the cams are advanced and the spread is kept within possible limits.

TABLE I—*Hydraulic Pump Data*

Make	Model	Type of Pump	Normal Speed R.P.M.	Output Gal./hr.	Pressure lbs./sq. in.
INTEGRAL .	B.H. Mk. II.	3-stage Gear.	2,250	180	600
DOWTY . .	Mk. I. & II.	Gear.	1,200	460	500

TABLE I—*Hydraulic Pump Data—continued.*

Make	Model	Type of Pump	Normal Speed R.P.M.	Output Gal./hr.	Pressure lbs./sq. in.
LOCKHEED .	Mk. III. Mk. IV. Mk. V.	Rotary.	1,300 1,300 1,300	2 × 32·5 65 32·5	850 850 850
ROTOPLUNGE .	R.	Piston.	1,200	70	400
TECALEMIT .	B.3 B.4	Rotary.	1,200 1,200	555 2 × 288 = 576	500 350
VICKERS . .	Mk. III.	Piston.	1,150	55	1,000
MESSIER . .	P.10 P.12 P.13 P.43.M.	Piston.	2,250 2,250 2,250 2,250	54 90 120 120	1,000–1,400 1,000–1,400 1,000–1,400 1,000–1,400
PESCO . .	204 196 203 247	Gear. Vane. Gear. Gear.	2,250 2,250 2,250 2,250	70 192 112 500	1,000 200 800 1,000
ROTAX-ECLIPSE	M. 3235 M. 3229	Rotary. Rotary.	3,000 3,550	274 90	400 800
SPERRY-NORTHERN	PL. 1335	Rotary.	2,100	150	200

TABLE II—*Vacuum Pump Data*

Make	Type	Normal Speed R.P.M.	Capacity C.F.M.	Suction "Hg.	Pressure "Hg.
PESCO . . .	B.1 B.2 B.3	1,500 1,500 2,250	6·0 5·0 11·5	4 4 4	1 1 16
ROTAX-ECLIPSE .	B.2a. B.3	2,250 1,500 2,250	8·0 9·3 10·5	4 4 4	1 1 16
TURNER-ROMEC .	B.2a.	1,500	4·5	4	1

MANUFACTURING ROUTINE

MAIN PLANE ASSEMBLY

THE work of assembly of both the centre and outer planes is carried out on suitable jigs which are so designed that they truly represent the basic points of the components and ensure interchangeability.

Centre Plane Assembly

For the centre plane we have already produced the spars in the detail stage jig-drilled along their length to correctly position, relative to the end fittings, all the various brackets and channels forming the attachments for the fuselage and engine mounting, and also the rib positions. Our jig for this component must therefore position the front and rear spars by means of the end fittings at the correct spar centres and truly in line laterally. Assuming that the centre plane is built up on edge with the leading edge at the bottom, our jig will consist of two structures built solidly into the floor at the appropriate distance apart to pick up on brackets the end spar fittings, provision also being made to support the front spar (lower one in jig) so that it does not bow under its own weight. The order of assembly will be as follows :—

(*a*) Spars placed in position in jig.

(*b*) Nose, centre and tail ribs fitted.

(*c*) Stringers fitted in place.

(*d*) Trailing edge fitted.

(*e*) All internal brackets and special bulkhead members secured in place.

(*f*) Upper skin fixing.

(*g*) Lower skin fixing.

Taking each operation in order, the special features to note are as follows :—

(*a*) This consists in securing the spars by their end fittings on to the jig brackets by means of special ground pins and ensuring, by using the blocks provided, that the lower spar is straight.

(*b*) The ribs are already jig-drilled at their points of attachment to the spar web, and the correct location already being provided, the work of assembly consists of riveting or bolting the ribs on at their correct stations. It should be noted that the rib flanges to which the skin is attached are undrilled at this stage. Assuming that trailing edge flaps are fitted, an attachment in the jig will provide the correct location for the tail ribs at the points picking up the brackets carrying the flaps.

(*c*) The stringers are located but not fixed in notches cut in the rib flanges for all ribs except at the end where they are riveted to give definite locations.

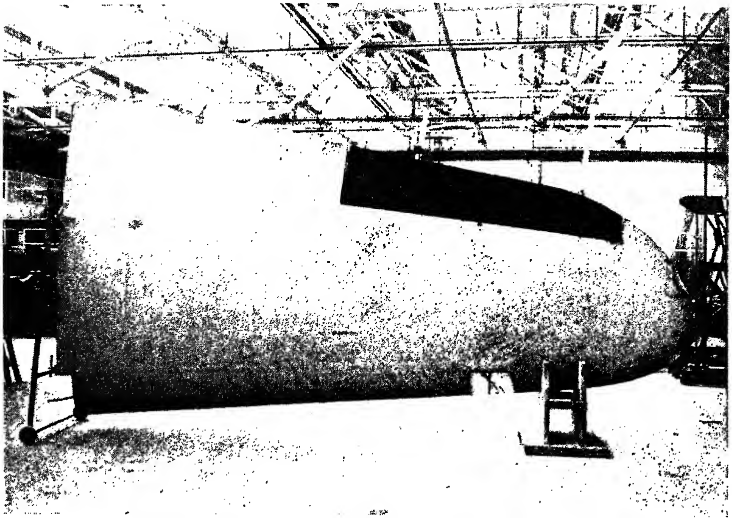


Fig. 1.—OUTER PLANE OF THE BRISTOL BLENHEIM BOMBER.

(*d*) The trailing edge members made from extruded sections in light alloy are now secured in position by riveting to the tail ribs, and for this operation a spacer bar is carried on the jig to locate the tips of the tail ribs.

(*e*) Before the skin covering is fitted all subsidiary details are fitted into place, such as control brackets, special members in the centre forming the bomb cell station, members forming the upper support for the skin covering in way of the fuel tanks, etc. These members are all riveted or bolted in place at stations previously jig-drilled.

(*f*) Skin covering the upper surface is now carried out. The sheets are cut to template and correctly drilled from standard drilling shrouds. Each sheet is offered up to its station and the rib flanges drilled through the holes in the sheet. The ribs are free to move sideways to a certain extent and to ensure the holes are drilled correctly through the flanges a centre line is marked in pencil on the flange. The rib can then be moved into its correct position by observing the centre line through the holes in the sheet, and the drilling operation carried out. The sheets are now riveted on to the structure in their correct sequence.

(*g*) The covering of the lower surface is carried out as for the upper surface. Special holding-up equipment may be essential for this operation, as access is only obtained through lightening holes in ribs for a portion of the riveting.

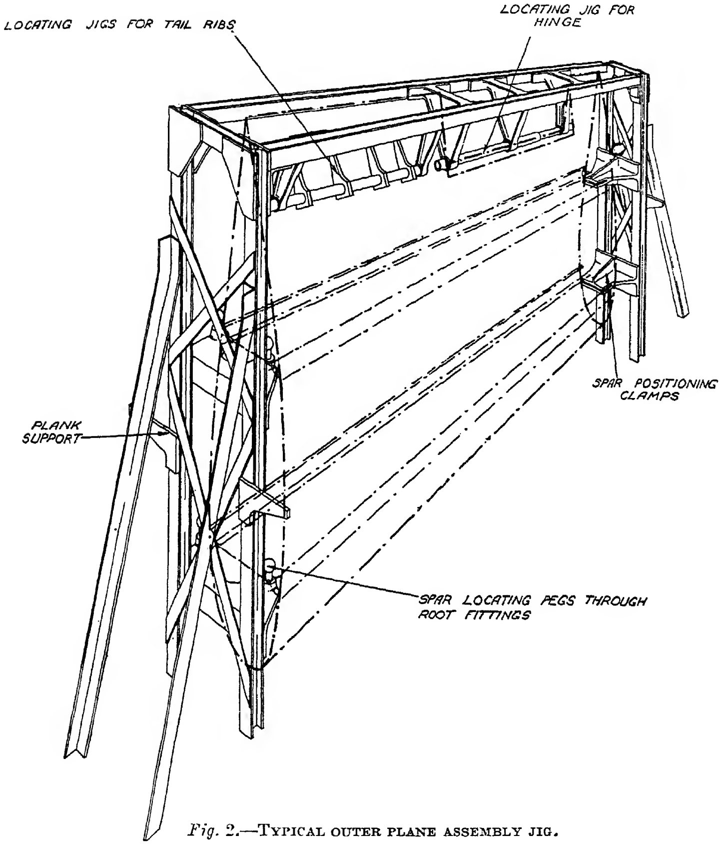


Fig. 2.—TYPICAL OUTER PLANE ASSEMBLY JIG.

Alternate Assembly Operation

With reference to centre plane assembly it should be noted that the trailing edge portion is so designed that it is possible to assemble all tail ribs and skin covering aft of the rear spar on to the rear spar as a separate operation. With this portion completed it will then pass forward for assembly on the main jigs.

OUTER PLANE ASSEMBLY

For this group we have our jig-drilled spars as for the centre plane. Regarding assembly jigs (see Fig. 2) the inner ends of the spars are to

match correctly the pick-up points on the centre plane spars. For the outer ends of the spars (see Fig. 1) we have no special matching points to consider, and so our jig is called upon to act as a spacer for the spars. On the outer planes, stations for the aileron hinges are provided, and to ensure interchangeability of components the assembly jig must carry location fixtures for these points, and also a means of checking the accuracy of the clearance given between the end ribs of the aileron and the rib providing the gap for same. Another piece of equipment necessary on this assembly is a gauge for checking that correct clearance is provided between the aileron leading edge and rear fairing piece on the plane in addition to the end clearances. With regard to the fitting of the wing tip, this is secured by means of screws which pick up nut plates carried on the end rib of the outer plane. This feature can be noted on reference to Fig. 1. The trailing edge flap attachments are dealt with in a similar manner to the centre plane.

Assembly operations will follow generally those for the centre plane. An additional detail to be fitted is the fairing piece at the trailing edge of the plane in way of the aileron. This being fitted on completion of the covering operation, rivets are used which can be inserted from the outside. With the covering fixed in position the holes in the outer rib for picking up the wing tip securing screws are jig-drilled, using the leading edge (not the spars) as a location to ensure true matching of the skin covering.

Wing Tip

This component, as previously pointed out, is secured to the outer plane by screws picking up jig-drilled points. The detail structure consists of diaphragm ribs carried on light former members covered with a light alloy skin, and having as a finishing outside edge a channel member wood-filled. An inner end rib is positioned to butt up to the end rib of the outer plane. The assembly jig holds the ribs and formers in position for skin covering, and with this part complete, the inner end is jig-drilled for the screw attachment holes.

Ailerons

Assuming that the aileron design is based on a torque tube as the main member, our group of additional details will consist of the following :—

(*a*) Ribs made from sheet as pressings and carrying collars for fixing rib to the torque tube.

(*b*) Leading edge in metal or wood.

(*c*) Trailing edge.

(*d*) Cover strip for the top surface.

(*e*) Control lever and hinge details.

(*f*) Fabric covering.

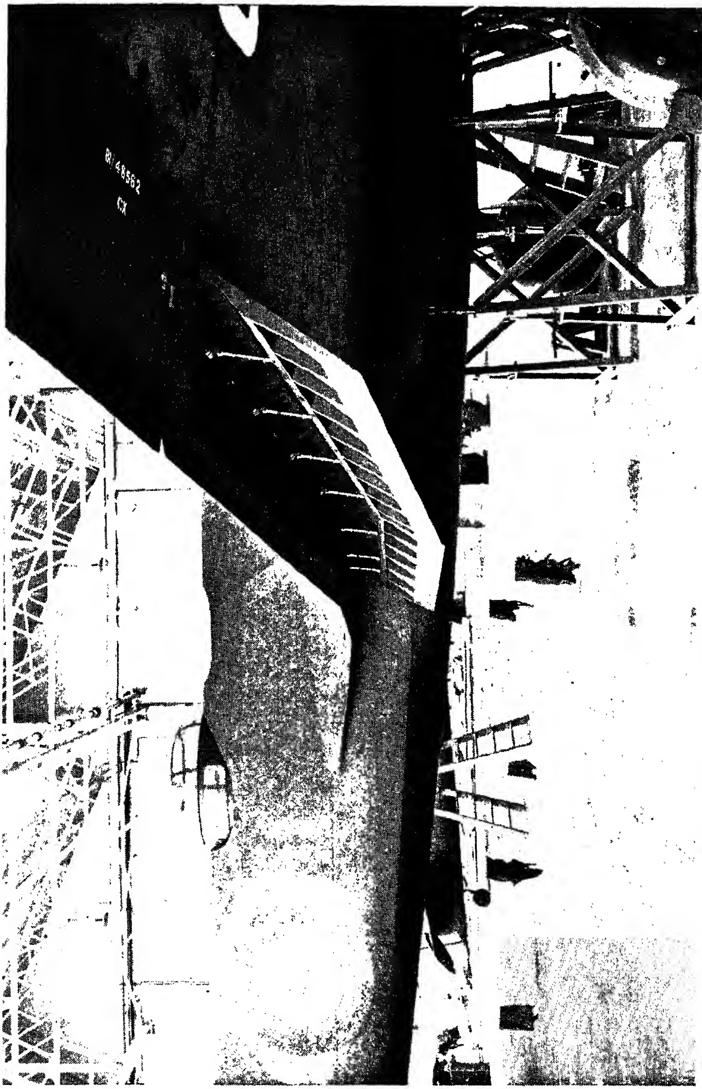


Fig. 3.—THE SPLIT TRAILING-EDGE FLAPS ON THE BRISTOL BLENHEIM BOMBER.

Aileron Assembly

The torque tube will be jig-drilled along its length for rib collar pins, hinge fittings and control lever attachment bracket. The jig, therefore, will carry the torque tube with true locations for the hinge fittings and brackets. In addition, the rear tips of the ribs will be located by a spacer bar to hold them in correct position when fitting the trailing edge member. The order of assembly will be as follows :—

(*a*) Ribs threaded on to torque tube in their correct sequence, the control lever fittings and centre hinge being already in place on the tube.

(*b*) Outer hinge fittings inserted in torque tube and secured.

(*c*) The structure is now placed in the jig and the ribs pinned in position on the torque tube.

(*d*) Trailing edge member fitted.

(*e*) Leading edge secured in place.

(*f*) Cover strip riveted to ribs.

(*g*) Fabric covering placed on.

(*h*) The finished unit checked by gauge for overall dimensions to ensure correct clearances when fitting to outer plane.

TRAILING-EDGE FLAPS

It will be noted upon reference to Fig. 3 that the detail arrangement of the flaps, both for centre and outer portions, provides for an auxiliary spar member carrying the hinge, the member being secured to the plane by brackets picking up on each tail rib member. This auxiliary spar will therefore be jig-drilled for bracket positions so that they correctly match the plane tail rib pitch and, in addition, the hinges carried on the lower rear edge will also be secured on jig-drilled points. The brackets carrying the auxiliary spar also serve to house the guide bearings for the operating tube which travels in a lateral direction through the bearings when actuating the flaps. The flaps themselves are fully metal-skin covered on the underside and only partially on the upper surface, and consequently the operation of attaching the covering is simplified for this component.

The assembly method necessary for building the flaps must ensure that the hinge positions are correctly spaced to mate with those on the auxiliary spar, and that the end ribs are at their true position relative to datum. In addition, the jig must carry the necessary means for holding the ribs in position during the skinning operation. The actual assembly has no special features to note beyond the fact that rivets which can be inserted from the outside are necessary for securing certain of the details as the last operation.

EXPERIMENTAL TESTING OF RADIAL AIR-COOLED AERO ENGINES

By G. O. Anderson, A.M.I.Ae.E.

In this article it is intended to describe some of the tests carried out during the experimental development of the main engine prior to attempting a type approval test.

The Experimental Test Department usually prepares a definite programme for each type of engine, but of course this frequently has to be modified in certain respects depending upon the problems which arise as the test proceeds. Nevertheless, all the items included in the original programme are thoroughly tested to ensure that the engine will not only complete the type test satisfactorily, but also that there will be little or no difficulty in production testing or in actual service, whether it be civil or military.

Experimental Engine. Preliminary Tests

During the initial tests of a new engine even though it is not of entirely new design, it is advisable to adopt a "go-easy" policy. Therefore on the initial tests under power on the dynamometer the engine is opened up in stages and at each stage the cylinder temperatures are carefully recorded and all relevant data such as oil inlet and outlet temperatures and amount in circulation are logged. The cylinder temperatures are recorded on both plug and thimble couples, and recordings of the barrel and head temperatures are achieved with the aid of a point couple. This latter couple can be applied at any required position by pressing the point into the metal. Fig. 1 is the cylinder temperature recording apparatus used by the Bristol Aeroplane Company Ltd., Engine Dept., showing the points of attachment of the various couples. Fig. 2 is a photograph of the actual type of pyrometer box with multi points used on experimental engines, while Fig. 3 shows the type of apparatus used in flight.

The recording instrument is of the galvanometer type. The true temperatures are not read direct from the instruments used on experimental engines, but are determined with the assistance of calibration charts which are prepared for each batch of the copper-constanton couples. Readings are taken from the chart corresponding to the instrument reading and the cold junction temperature is added.

The ordinary domestic thermos flask filled with oil or a mixture of ice and water serves quite well as a cold junction when a small number of couples is used, but for the experimental apparatus a junction box is employed having all its terminals covered with a heat-insulating powder.

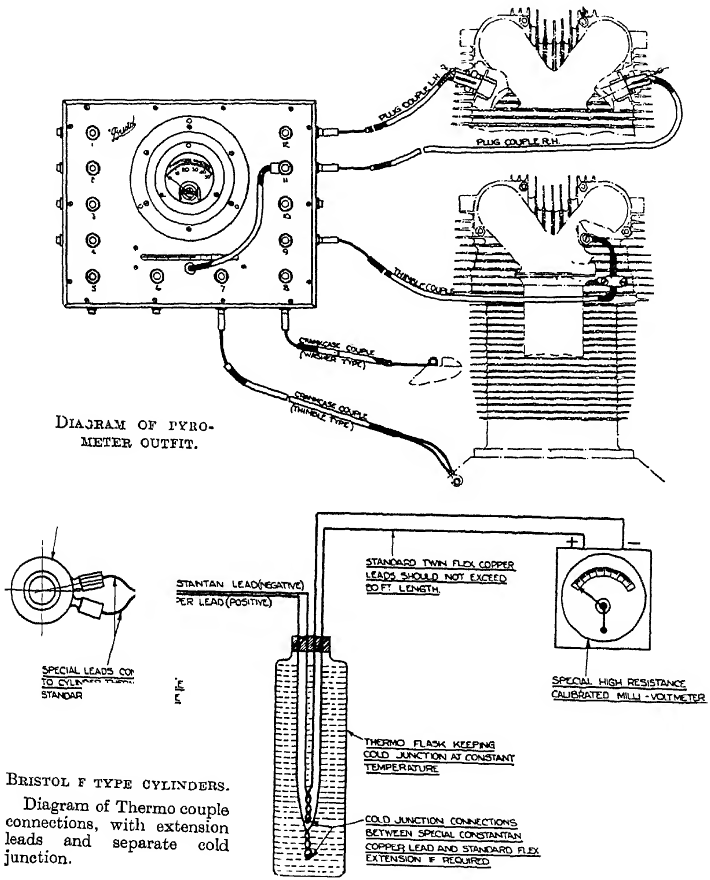


DIAGRAM OF PYROMETER OUTFIT.

BRISTOL F TYPE CYLINDERS.

Diagram of Thermo couple connections, with extension leads and separate cold junction.

Fig. 1.—CYLINDER TEMPERATURE RECORDING APPARATUS USED BY THE BRISTOL AEROPLANE COMPANY LTD.

At each stage during the opening up of the engine the recorded temperatures are analysed and any adjustment of the fuel consumption which may be necessary to keep them well below the limit is made.

As a preliminary endurance the engine is run for two hours at a nominal power of about 70 to 80 per cent. of the ultimate endurance power of the engine. No effort is made to tune the carburetter or attain

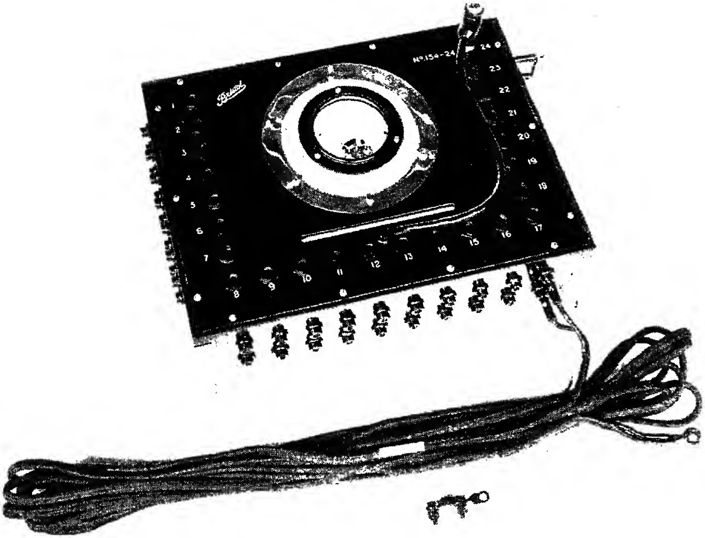


Fig. 2.—TYPE OF PYROMETER BOX WITH MULTI POINTS USED ON EXPERIMENTAL ENGINES.

high powers, but careful checks are made of the oil return, *i.e.*, the amount circulating through the engine, the oil temperatures and the consumptions. The usual observations for oil leaks, vibration, loss of engine speed, when switching the magnetos off alternatively, are made, but take the form of a preliminary check only, no attempt being made to investigate the performance over a complete range of speeds. It is advisable also to examine the pump filter at every opportunity when the engine is shut down.

On the completion of the two hours the engine is returned to the shop for a complete strip and examination, and the future order of events will depend upon its condition.

Oil Circulation Investigation

It may be deemed advisable as a result of the condition of certain of the components to carry out an investigation into the amount of oil in circulation in the various compartments of the engine. This is accomplished by building up the engine with each section, such as the reduction gear, front cover, crankcase, blower drive casing and rear cover, having a separate external oil drain. On the test stand these drains are led to a temporary external sump and with the engine running over a range of

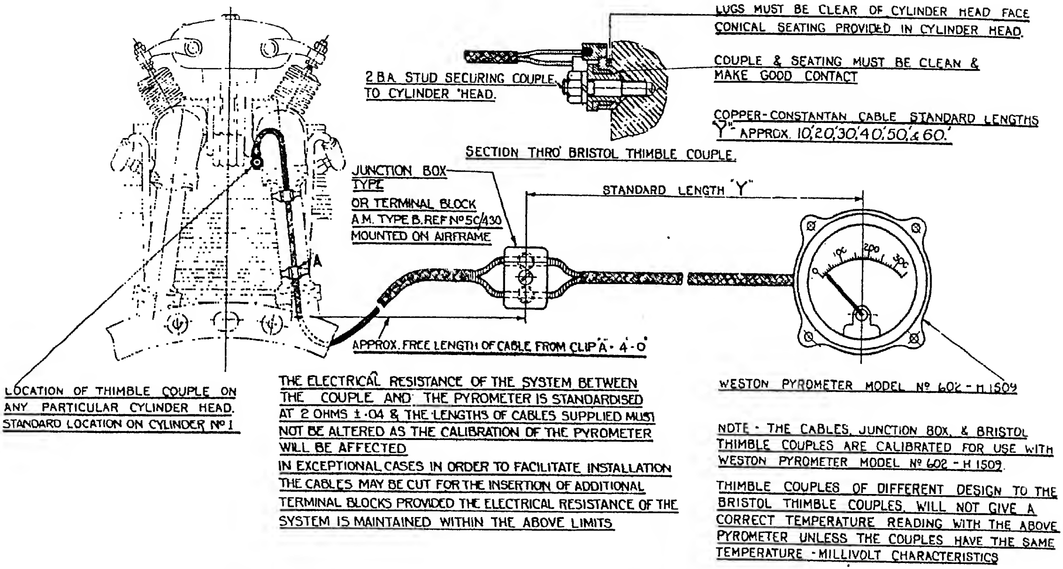


Fig. 3.—Bristol single couple temperature measurement equipment.

speeds and oil inlet temperatures the circulation through each section is measured with the aid of a 2-gallon, 1-gallon or even a cubic centimetre glass measure, depending upon the rate of flow, over a period of not less than half a minute. The engine scavenge pump which is normally connected to the sump is connected to the temporary drain tank instead. The scavenge pipe is connected to the filter situated in a depression or well in the tank. This ensures that the tank is being continually drained, and enables the test to be carried out over extended periods of running.

As a result of the analysis of the data obtained in this way it may be decided to reduce or increase the oil circulation in certain sections of the engine which would necessitate a repetition of the test procedure.

Power Output

When the oil circulation is satisfactory a stage may have been reached when it is considered advisable to check the power output. It is not intended to enter into detailed description of investigations into valve timing, as this is usually carried out on the single cylinder research units prior to the main engine tests.

The power check takes the form of an endurance run of two hours at the estimated cruising boost and maximum cruising r.p.m., and five minutes at maximum climbing boost and maximum climbing r.p.m. The altitude boxes are then fitted to the air intake and a series of check runs are made at international r.p.m. with the depression in the boxes corresponding to 1,000 ft. and 500 ft. above the estimated rated altitude, at the rated height, and 500 ft. and 1,000 ft. below this height. The ground level power at maximum climbing boost is examined from the point of view of its relation to the altitude power. If the estimate of the supercharger blower performance has been correct, then the corrected boost on the altitude check at rated height should agree with the maximum climbing boost at sea level.

Should the corrected boost at the desired altitude be low, resulting in a lower power than was anticipated, the cause may be too small a choke, and further altitude power readings are required with various sizes of chokes fitted to the carburetter until the optimum size is determined. It is advisable to keep the chokes as large as possible, with due regard of course to the requirements for satisfactory acceleration.

If the increase in choke size does not produce the desired effect then it may be necessary to fit a larger impeller. This unfortunately necessitates an increase in the rated boost, for it will not be possible to obtain the same power at ground level as with the smaller impeller, owing to the increase in power absorbed in driving the larger impeller and the increased temperature rise consequent to the increased blower compression ratio.

Consideration will have to be made as to whether the engine will run satisfactorily with the larger impeller. The engine may be so near to

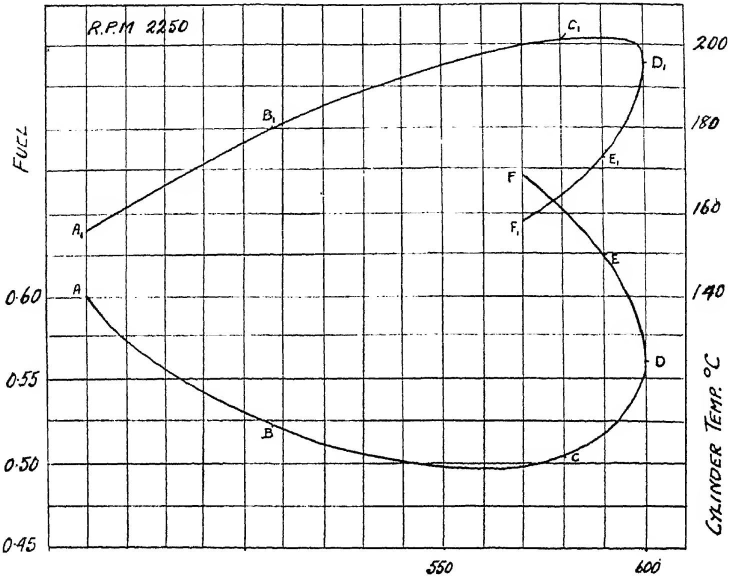


Fig. 4.—FUEL CONSUMPTION LOOP.

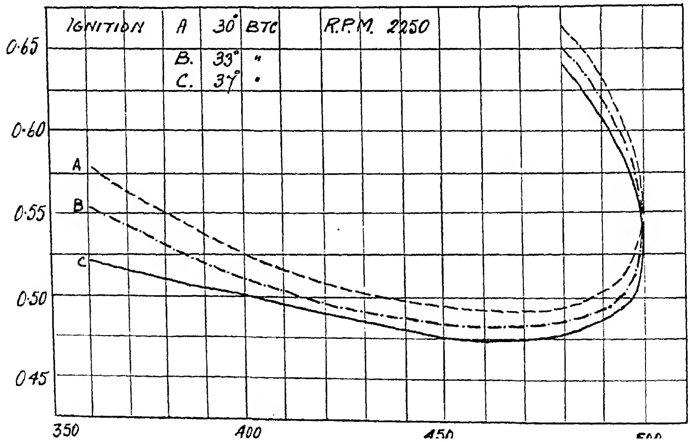


Fig. 4A.—IGNITION—FUEL CONSUMPTION.

detonation with the smaller impeller that it may be a risky procedure to increase the boost pressure by fitting the larger one. It may, however, be possible to maintain the margin of safety by an increase in the fuel consumption. If this course is inadvisable then an alternative procedure is to maintain the same rated boost with the larger-diameter impeller as had been intended for the smaller impeller, or even slightly reduce it and increase the rated altitude, *i.e.*, the height at which rated boost is attainable with the throttle fully open at international r.p.m.

When the engine develops more power at rated boost at sea level than was expected then a lower rated altitude may be decided upon, or the rated boost may be lowered, and the rated height maintained at its original estimated figure even though the power is higher than expected. Alternatively, if it is considered that the high power does not leave sufficient margin of safety the impeller may be cropped, *i.e.*, reduced in diameter.

It will be appreciated that the ratings can be conjured with in a variety of ways. Every suggestion has to be considered on its merits with particular reference to the effect on cylinder temperatures, fuel consumption, stressing of components and of course reaction to type test conditions, always bearing in mind the operating conditions for the aeroplanes for which the engine is intended.

Having decided the carburetter choke and the impeller size, a series of constant boost curves should be run at boosts varying from, say, zero to maximum take-off boosts, and the fuel consumption varied. From the cylinder and crankcase temperatures recorded on these tests a suitable range of fuel consumptions can be determined.

Fuel Consumption Loops

It is advisable when determining the fuel consumption at certain basic conditions which form the main points on the throttle curve to complete a series which are usually termed fuel-consumption loops. These are carried out in the following manner:

The brake load and throttle are adjusted at first to give a desired cruising power at a cruising speed at a mixture strength which is neither too rich nor too weak to cause a loss of power. The throttle is locked in this position and the fuel consumption is then increased by operation of the mixture control. This results in a variation of power, but the throttle is not altered and the r.p.m. are returned to their original figure by adjustment of the brake load. The power, fuel consumption and cylinder temperatures are then logged, together with other relevant data. The next step is to reduce the fuel consumption about 4 per cent. and again regain the r.p.m. by adjustment of the brake and log the various readings. This is repeated several times, and when the results are plotted the loop from which the curves get their name is the result.

It will be noted that by commencing the loop at a rich mixture the

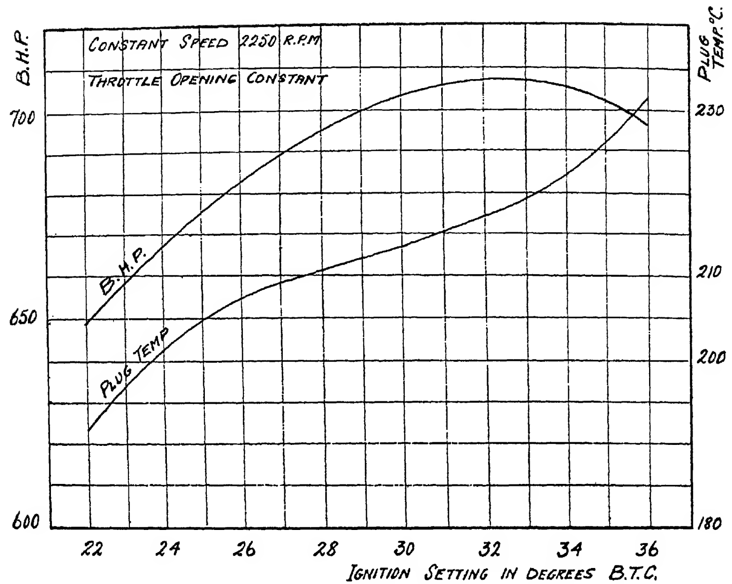


Fig. 5.—IGNITION LOOP.

reduction of the fuel consumption produces a gain in power until the position of weakest mixture for maximum power is reached. From then onwards a reduction in the fuel consumption results in a loss of power. This loss in power is a greater percentage than the reduction in total pints of fuel used, resulting in an increase in the specific consumption causing a " tip up " of the curve as shown in Fig. 4. These curves have been drawn as examples of the results obtained, and are not obtained from any particular engine.

The loops are prepared over a range of powers and are in many instances repeated with various ignition settings, more especially when the engine is to be fitted with a variable ignition control.

Ignition Loops

Another form of loop which is frequently carried out to determine the most satisfactory magneto timing for a specific condition of horse power and r.p.m. is the ignition loop. This is accomplished by fitting a pointer on the contact breaker variable timing arm. The throttle and load are adjusted with the engine running at estimated normal ignition setting and the throttle is then locked in this position.

The ignition is then varied and with the specific fuel consumption maintained constant the variation in power at each setting is recorded together with the cylinder temperatures. Fig. 5 indicates the type of results obtained, but again the example is not taken from any particular engine.

Tuning

With the aid of the fuel-consumption loops and the ignition loops, the tuning positions of the carburetter and their respective optimum fuel consumption can be settled and the tuning is accomplished as described in Vol. II, p. 253. It is important to note, however, that modern carburetters are fitted with automatic mixture controls, and consequently the jet sizes have to be calibrated to give the desired economic tuning. The normal tuning curve is attained by increasing the fuel consumption by a fixed percentage by operation of the servo mechanism of the mixture control.

For carburetters not fitted with an automatic mixture control the jets are calibrated to give the desired normal consumption throttle curve, since the economic fuel consumption can be attained by hand operating the mixture control over any required range, the required movement from normal ground level setting of the control cock increasing as the altitude of the aeroplane increases. The operation of the carburetter controls has been described elsewhere (see article on "Carburation," Vol. I, p. 88), and need not be repeated here.

Starting, Slow Running and Acceleration

At the first available opportunity the engine is erected on a hangar test stand and fitted with a flight airscrew. The various forms of starting apparatus likely to be employed on the engine in service, such as the hand inertia starter, the electric starter and the cartridge starter, are used with the engine both cold and hot. A large number of these starts are carried out with varied amounts of priming of fuel into the induction system, so that data for service use can be prepared. During electric starting tests the following data is recorded on each start or attempted start, priming to engine, period switch is in operation, motor volts, battery volts, current amps (mean and maximum) and atmospheric temperature. In many instances the engine is removed from the hangar test stand and mounted on a stand and moved bodily into a refrigerator chamber. Here tests are carried out at sub-zero temperatures to determine the effect required to turn the engine and the rate of turning with each starter, then with the engine still cold it is transferred as quickly as possible to the hangar stand again when cold starts are carried out.

Throttle curves are carried out with various types of airscrews, the whole range of speeds of the engine explored for "flat" spots, and then the engine is accelerated both slowly and rapidly from various throttle

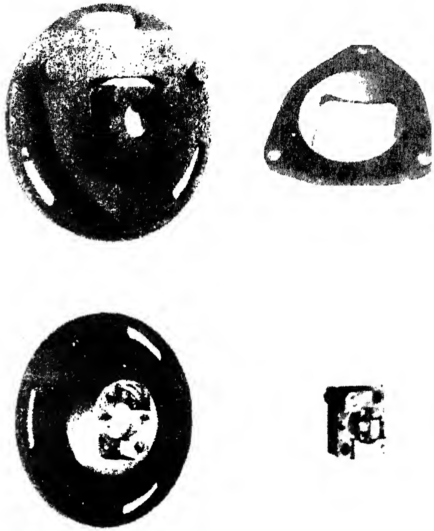


Fig. MIRROR HOUSINGS.

positions, special attention being paid to operation of the throttle to the take-off position from slow running and taxying speeds.

Torsiograph Tests

While the engine is on the hangar it may be a convenient opportunity to test the crankshaft for torsional vibration.

The R.A.E. mirror torsiograph is the type most frequently used. This apparatus consists of a stiff actuating steel tube fixed to the crank end of the hollow airscrew shaft and supported on a ball bearing in an adapter attached to the airscrew shaft. The instrument carries two mirrors, one of which is fixed to a stirrup which is tilted by the relative angular movement between the actuating tube and the front of the airscrew shaft. The other mirror is attached to a member mounted on ball trunnion on the adapter and is adjustable. This second mirror forms the base circle of the torsiograms (see Fig. 6).

A camera box and a powerful concentrated electric light are used to enable a permanent record of the torsiograms to be taken, the apparatus being mounted as in Fig. 7. As the operator has to stand immediately in front of the airscrew a guard of torpedo netting is provided.

The camera box is fitted with a ground glass on which spots of light from the mirror are reflected. In setting the mirrors the airscrew is revolved slowly to determine the position of the reflected light and the pivoted mirror is adjusted so that its spot of light describes a circle of about 2 in. in diameter. The light spot from the other mirror must be adjusted to give a base circle within the boundaries of the plate and the two light spots must be in line radially.

Observations are made of the diagram on the ground glass screen with the engine running; if everything is satisfactory a series of plates are taken with the engine running at various speeds, say, one every 100 r.p.m.

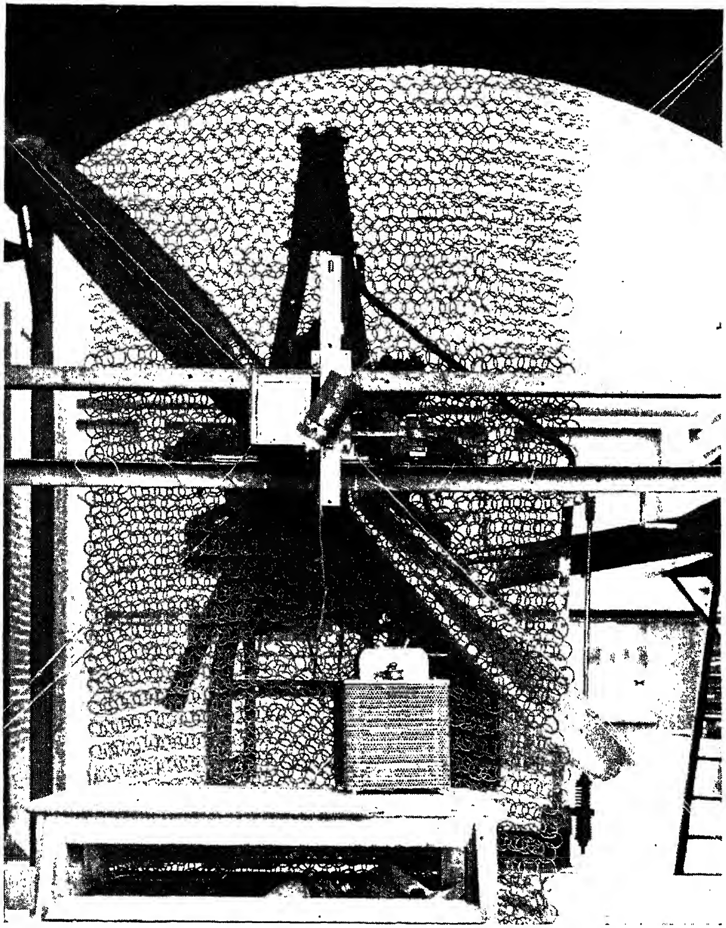


Fig. 7.—TORSIOGRAPH INSTRUMENT MOUNTED ON ENGINE ON HANGAR TEST STAND.

Only one, or perhaps two, revolutions of the engine are required for each exposure, and in order to allow for the variation in engine speeds the height of fall of the shutter is adjusted at each speed.

Any torsional vibration is evident from the irregularities of the inner circle relative to the base circle and the synchronous speed can readily

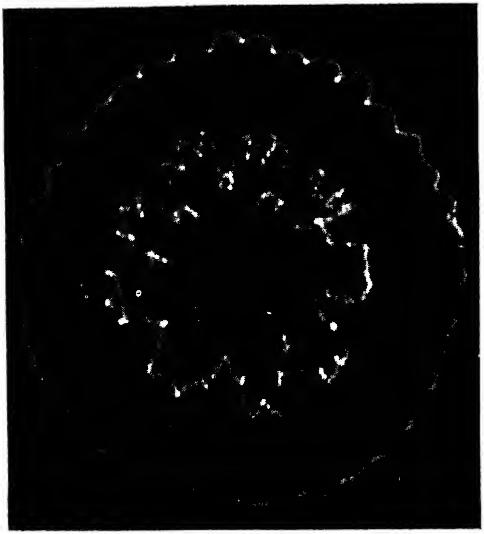


Fig. 8.—An example of a photograph of the track of light spots reflected from mirrors.

be determined from the results. Fig. 8 is an example of a photograph of the track of the light spots reflected from the mirrors.

Exhaust Gas Analysis

The method usually employed in actual service to attain the desired fuel economy at cruising conditions is to operate the mixture control until a definite percentage drop in r.p.m. occurs and then regain the original r.p.m. setting by opening the throttle.

When, however, the engine is fitted with a constant-speed variable - pitch airscrew, this method obviously cannot be adopted, for as the r.p.m. tend to reduce due to the weakening of the mixture they are recovered by the governor control incorporated in the airscrew constant-speed mechanism.

The use of a carburetter fitted with a reliable automatic mixture control is the most satisfactory solution to this difficulty, but when the engine is not fitted with this type of carburetter and is intended to be fitted with a constant-speed variable airscrew during its early experimental flight tests, exhaust gas analysers are frequently used.

There are several types of these instruments, such as the Moto-Vita Cambridge, Breeze, etc., and it is advisable to precede flight tests with test bench checks to determine the relation between the desired economic specific fuel consumption and the reading on the instrument scale.

It is claimed that these instruments record instantaneous readings of the percentage of unburnt combustibles in the exhaust gas.

The principle of the various types is similar. In the case of the Moto-Vita, for example, a sample of the exhaust gas is conducted from the cylinder exhaust snout and thoroughly mixed with air in an enclosed chamber and then passed over an element consisting primarily of platinum wires connected in the form of a "Wheatstone Bridge." Two of the arms of the circuit are bare and the other two are covered by a fine glass tube

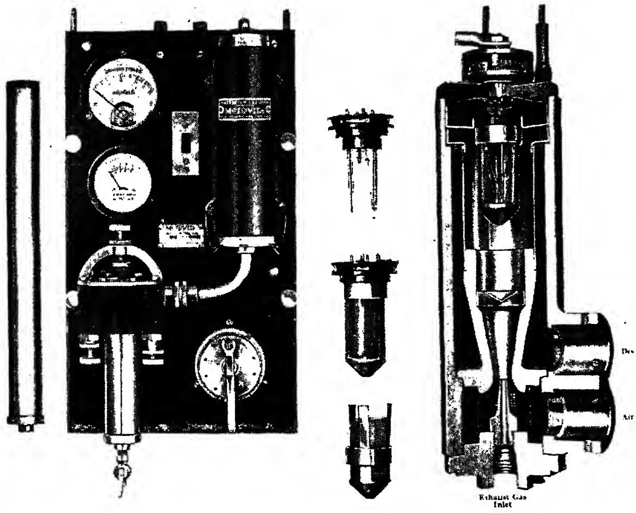


Fig. 9.—FRONT PANEL OF THE MOTO-VITA INSTRUMENT.
Showing the spring-loaded disc valve in the right-hand corner of the panel.

fixed to the wires to render them non-active catalytically. Across the bridge is connected the indicating instrument, the other two opposite corners being connected to a battery.

When a combustible vapour passes over the circuit surface combustion takes place on the active wires and thus unbalances the bridge. The degree of unbalancing is proportional to the richness of the fuel mixture, *i.e.*, the unburnt combustibles in the exhaust gases. Fig. 9 shows the front panel of the Moto-Vita instrument.

This instrument is sometimes used for checking distribution on experimental engines. Pipes are led from an exhaust snout from each cylinder to a control valve and a check valve is interposed to damp out the pressure waves and to maintain a pressure drop across the analyser unit of not more than 2 in. of water. The gases pass into the analyser *viâ* a venturi nozzle, which not only serves to draw in fresh air, but produces a homogeneous mixture. As the gas passes through the unit, some passes through the screen surrounding the "Wheatstone Bridge" element and produces the action already described. The exhaust gas may be taken from any cylinder at will, with the aid of a spring-loaded disc valve, shown in the right-hand corner of the panel, Fig. 9.

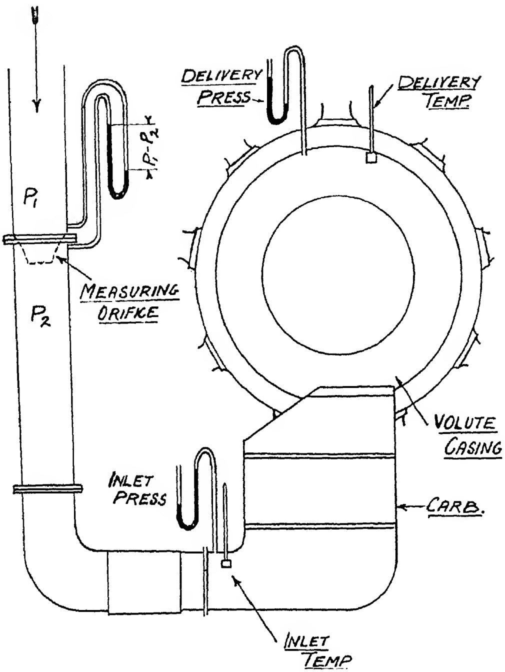


Fig. 10.—APPARATUS FOR MEASURING QUANTITY OF AIR.

When the instrument is being checked for flight, it is usual to have a single course for the exhaust gas sample. The specific fuel consumption is carefully recorded and tabulated together with the actual instrument reading, and in addition on experimental engines the amount of air being used is measured with the aid of the apparatus and formula given in Figs. 10 and 10A.

A diagrammatic sketch of the installation of the Cambridge Exhaust Gas Analyser is shown in Fig. 11.

Indicator Diagrams

Another method of checking distribution is by means of an indicator. One of the most satisfactory types of indicators used on experimental engines is the R.A.E., shown in Fig. 12. With the aid of this instrument the characteristic of the combustion chamber and the effect of variations of mixture strength, ignition timing, boost pressure, etc., can be studied; the results also serve as a useful check on distribution.

Briefly the indicator consists of (*a*) a balanced disc valve unit fitted to the cylinder, usually in one of the plug holes, (*b*) a compressed air-operated piston with restraining spring operating a linkage (*c*), having a sparking point (*d*) connected electrically (*e*) to the disc valve unit. The spark point moves in a horizontal line along the drum (*f*), which is chain driven from the main engine *viâ* a clutch.

Components (*a*) and (*b*) are connected to a high-pressure air bottle (*g*).

The operation of the indicator is as follows :—

The valve in the disc valve unit fitted to the cylinder is free to move

a very small amount (less than 0·01 in.), and one side of the disc is subject to the pressure in the cylinder, while the other is acted upon by the pressure of the air from the bottle. When the disc is seating the electrical circuit is complete, but when it floats the circuit is broken and an electrical spark occurs and punctures the black paper fitted to the revolving drum.

When the air is released from the bottle the pressure is allowed to increase very gradually and the spark point travels along the revolving drum, perforating the paper as it travels in the manner shown in Fig. 13.

A line is drawn through the mean of these points and the actual indicator card is prepared in the more familiar form shown in Fig. 13A, knowing the rate of the springs in unit (*b*).

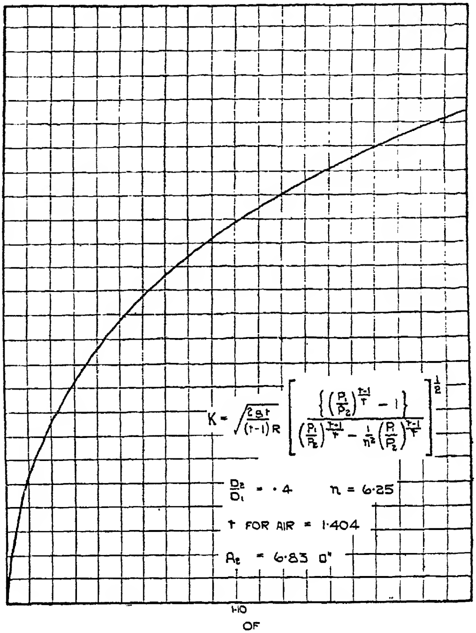


Fig. 10A.—FORMULA FOR MEASURING QUANTITY OF AIR.

P_2 = Final press " Hg "

RATE OF FLOW (GERMAN NOZZLE)

148

LBS/MIN.

P_1 : Initial press ' Hg."

Cd 0·98.

Morse Test

A simple and approximate method of determining the mechanical efficiency and determining whether each cylinder is doing its fair share of work is the " morse test." In using this method the engine is run at some predetermined power and r.p.m. and each cylinder is cut-out in turn and the r.p.m. brought back to the original speed by operation of the brake, the throttle being kept locked in the one position. Thus on a nine-cylinder

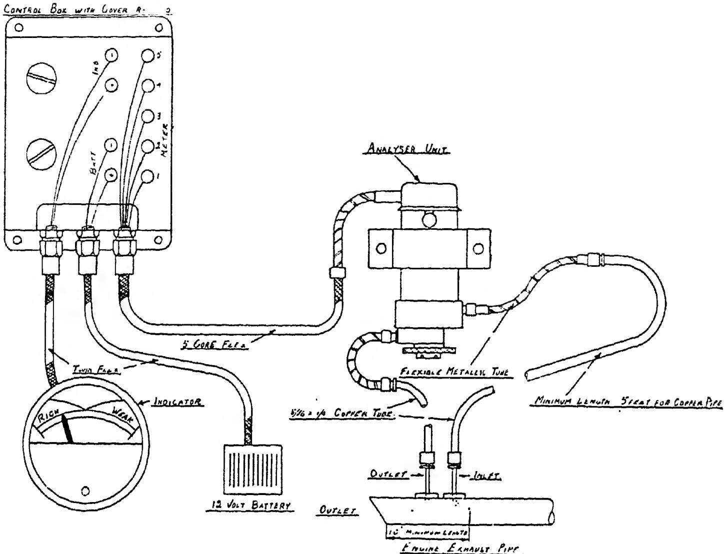


FIG. 11.—DIAGRAMMATIC SKETCH OF THE INSTALLATION OF THE CAMBRIDGE EXHAUST GAS ANALYSER.

radial engine eight of the cylinders are firing, but the power is less than 8/9 of the original power due to the friction and other losses of the cylinder which is not firing.

Example of results :—

	Engine r.p.m.	B.H.P.	B.H.P. loss
All cylinders firing	2,250	600	—
No. 1 out	,,	512	88
,, 2 ,, . .	,,	512	88
,, 3 ,, . .	,,	516	84
,, 4 ,, . .	,,	511	89
,, 5 ,, . .	,,	515	85
,, 6 ,, . .	,,	509	91
,, 7 ,, . .	,,	516	84
,, 8 ,, . .	,,	517	83
,, 9 ,, . .	,,	516	84
Total .			776

$$\text{Approximate mechanical efficiency} = \frac{600}{776} = 77{\cdot}3 \text{ per cent.}$$

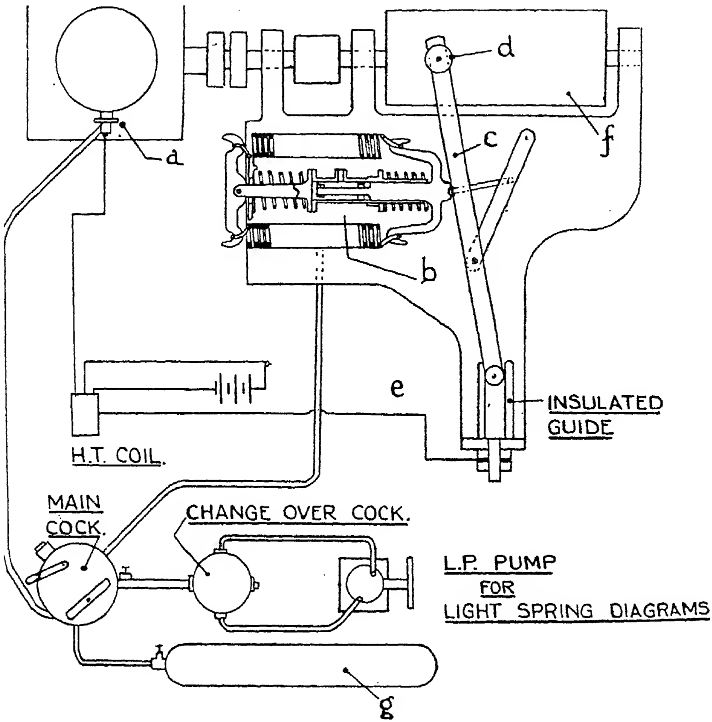


Fig. 12.—THE R.A.E. INDICATOR.

Freezing Tests

If the experimental engine being tested incorporates certain innovations in the design of the induction system, it is often desirable to carry out tests to determine the anti-freezing properties of the system.

It is a well-known fact that, owing to the low depression immediately above the choke and the high latent heat of evaporation of the fuel, any moisture in suspension in the fuel air-mixture tends to separate out in the form of ice which collects on the slightest projection and would gradually build up and cause a restriction. It is important, therefore, during the early stages of the development of the engine to determine the location of the points at which the ice has a tendency to form so as to be able to provide suitable safeguards to eliminate the possibility of the

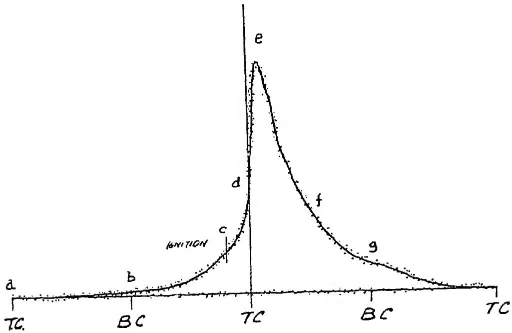


Fig. 3.—DEVELOPMENT OF PERFORATIONS. DRUM SPEED = ½ ENGINE SPEED.

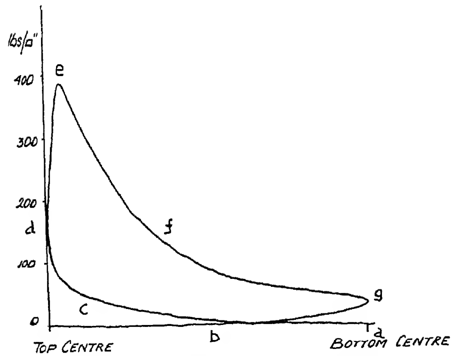


Fig. 13A.—PRESSURE-VOLUME DIAGRAM.

ice collecting in large enough quantities to choke the air flow and cause loss of power.

It is impossible of course to produce freezing at will under any atmospheric conditions, since a high percentage humidity and fairly cold temperature are required. However, in order to provide the necessary moisture, water is injected into the air intake in the form of a fine spray through a small nozzle. The water is forced through the nozzle by means of air pressure from an air bottle, and the rate of injection is varied by altering the pressure.

The engine is run on a hangar test stand and fitted with a "light" airscrew to facilitate the attainment of a high depression at small throttle openings. The engine is run at a predetermined speed with the throttle locked and the water injected at a fixed rate for a period of 10 or 15 minutes until a condition is found when freezing occurs, the signs that ice is forming being a gradual lowering of the r.p.m. In some instances the ice only forms to a limited extent and is then carried away owing to the high velocity of the fuel air mixture, and the r.p.m. immediately increase to their original figure. But in an investigation of this description the engine is shut down before the ice disappears and a note made of the locality of the ice formation.

In certain instances it may be difficult to see where the ice has formed and it may be necessary to fit celluloid or unsplinterable glass windows provided with wipers in certain parts of the induction system. With the aid of these windows and a small electric light fitted inside, the ice

formation can be observed as the test proceeds.

With this information available the necessary alterations to the design, or adequate precaution such as providing local hot spots by oil heating, can be made.

The water injection method is also used for determining the relative advantages of anti-freezing units such as the type which automatically injects alcohol when ice forms, and also "warning" units which operate a red lamp in the cockpit.

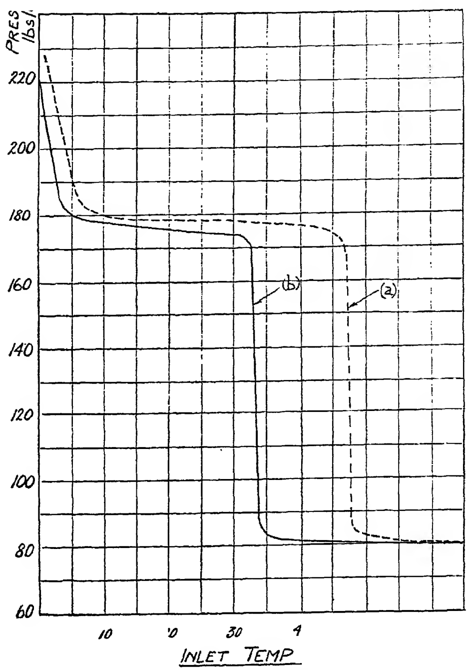


Fig. 14.—GRAPH OF PRESSURES PLOTTED AGAINST INLET TEMPERATURES.

Calibration of High Initial Oil Pressure Device

An important test on some of the more recent types of engines is the calibration of the high initial oil-pressure pump. The object of fitting this type of pump is to ensure that the engine is adequately lubricated even when it is started and immediately opened up to high speed when the oil is at very low temperatures. Thus on these occasions when it is imperative to get an aeroplane into the air as quickly as possible the use of the pump eliminates any necessity to idle and run light until the oil inlet temperature is increased.

At a fairly advanced stage in the development of the engine the functioning of this pump is checked on a hangar test stand. A temporary auxiliary oil tank is fitted at the engine and the pipe lines are kept as short as possible so as to avoid starving the pump when opening up at very cold temperature.

Oil is stored in the refrigerator until it has attained sub-zero temperature, and approximately 4 gallons are then transferred to the auxiliary tank on the hangar stand. The engine is started and immediately opened

up to take-off r.p.m., and boost and the oil pressure rises to 200 lb. per sq. in. Continuing to run the engine at take-off conditions, the oil-inlet temperature and pressure are logged every half minute until the normal working pressure of 80 lb. per sq. in. is reached. The results are then examined with the aid of the graph of the pressures plotted against inlet temperatures (Fig. 14).

It is intended that the oil pressure should be normal when the inlet has been increased to 35° C. and above this temperature the pressure is maintained constant. If, therefore, the initial results indicate that the oil pressure is still high, above 35° C, curve (*a*), Fig. 14, then it is necessary to reduce the restriction to the oil flow. This is accomplished by machining away a small amount of the component which forms the restriction and which exerts an effort, depending upon the viscosity of the oil, to operate a spring-loaded valve. If this effort is decreased then the valve shuts earlier and the calibration curve (*b*), Fig. 14 is finally obtained by repeating the engine test already described until the decreased temperature at which the device is to cut-out is obtained.

Accessories

It is important before commencing the type test to make sure that all the accessory drives, such as those for the generator, air compressor, etc., are tested under full load. Therefore whenever possible these accessories are fitted and loaded to the conditions likely to be experienced in service with additional over-speed tests compatible with the conditions required on the type test.

The exhaust ring, which might also be classed as an accessory, is fitted on all long experimental endurance tests when the engine is erected on the hangar stand, and intentional back-fires are produced to stress the ring.

Final Stage Prior to Type Test

When it is considered that the engine development has reached a stage when the type test may confidently be attempted, a trial test should be run in the form of an abbreviated type test. The engine should be required to complete periods of a few hours at maximum cruising, climbing, and take-off conditions, totalling approximately 25 hours in all. On certain occasions it may be advisable to extend the test to 50 hours and arrange for it to take the form of a civil-type test.

MANUFACTURING ROUTINE

TAIL PORTION GROUP

INCLUDED in this section are the stern frame, tail plane, elevators, fin and rudder. The details and their manufacture are in general similar to those described for the fuselage and main planes. There are numerous points of interest connected with the component assembly methods adopted for this group and we will consider each in turn with particular reference to Fig. 1.

Stern Frame

This is obviously the key component of the group and carries the following attachment points :—

(*a*) A strap in the front end which overlaps the back former on the rear fuselage and is secured by set screws.

(*b*) Front and rear tail plane spar bolting points (the tail plane is of the fixed type) and also set screw positions for the angle pieces securing the junction of the tail plane and stern frame on the undersurface.

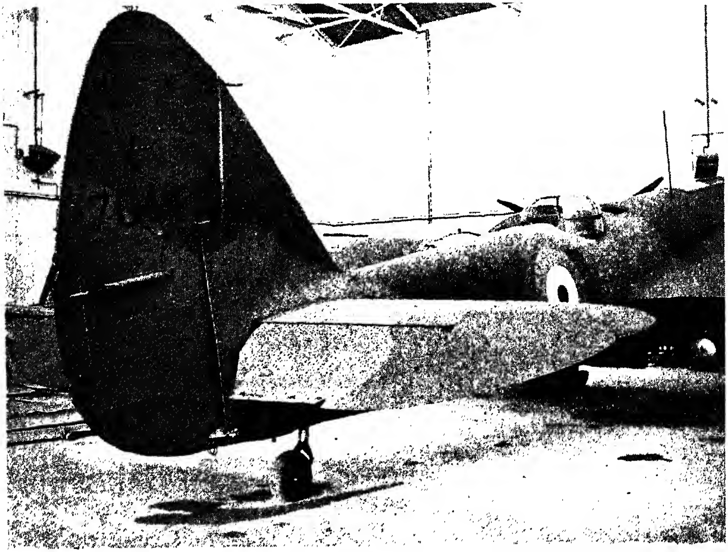
(*c*) Set screw centres to effect the junction of the stern post on back fin member and the rear former in the stern frame.

To manufacture this component as an interchangeable part the system of jigging must enable the whole of the above locations to be reproduced consistently and in correct relation one to the other. The assembly layout provides two jigs : the first upon which to build the structure accurately and the second for drilling and reaming all location holes. The building jig consists of a framework carrying peg location for setting up the front, rear and intermediate formers correctly. With these in position, the stringers are placed in the notches provided, and the skin covering is then riveted in position.

The frame is now removed and placed in position on the second jig, the set screw holes drilled through the various fixtures and the holes for the tail plane spar attachments reamed to size. This latter operation is very necessary, as even when the best possible building jig is used, there is bound to be a certain amount of internal strain set up when applying the skin covering which will cause change of shape in some direction, upon removing the component from the jig.

Tail Plane

The general construction and assembly follow closely the lines of the main planes. The matching points consist of spar bolts to stern frame, angles set screwed to stern frame, elevator hinges and screw positions for tips. The building jig will space the spars, already fully jig drilled, in their true relation to enable the structure to be built up and skin covered. The



[*The Bristol Aeroplane Co. Ltd.*

Fig. 1.—THE TAIL UNIT OF THE "BRISTOL" BLENHEIM BOMBER.

tail plane, less tips, will then be passed forward to the drilling jig for tip attachment screw holes, and also holes in angle for picking up stern frame. Gauges rotating on the elevator hinges will be necessary to check for elevator clearances, when the tip is finally assembled. The tip itself is assembled in a similar manner to the main plane tip.

Fin

The structure consists of ribs and spar members, the whole being skin covered. The rear vertical member (stern post) is carried down below the fin level into the rear former of the stern frame and secured by screws (see Fig. 1). Other attachment points are angles at the root junction with the tail plane attached by screws, and a bracket on the centre of the rear spar of the tail plane picking up a vertical member of the fin.

The first stage of assembly consists of building up the fin on a jig less the stern post and lower portion of the nose fairing. The component is then placed on an assembly jig, which carries the stern post already jig drilled in its true position relative to a duplicate of the rear tail plane bracket carried on the jig. The fin is bolted in position, the stern post fixing to fin skin completed and the root angles riveted in place and jig drilled. The fin is now ready for assembly to tail portion.

Rudder and Elevator

The construction for these components is relatively simple and the jigging for assembly offers no special problems. For the rudder the assembly matching points consist only of the hinges. Check gauges are necessary to ensure that correct clearances are maintained between rudder and fin. The elevator requires similar provision as for the rudder.

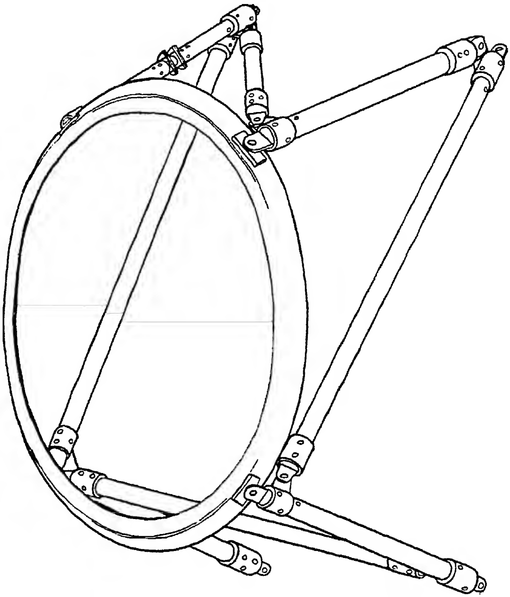


Fig. 2.—ENGINE MOUNTING STRUCTURE.

To complete the consideration of the component groups, we have the following remaining elements :—

(A) Engine Mountings and Nacelle Structure and Fairings.
(B) Landing Gears.
(C) Controls—Flying and Engine.
(D) Equipment and Furnishings.
(E) Fuel and Oil systems, including Tanks.

A. ENGINE MOUNTINGS AND NACELLE STRUCTURE AND FAIRINGS

The mounting and nacelle structure for a twin-engined aeroplane is usually divided into two portions, consisting of the part directly behind the engine, *i.e.*, the mounting, and the portion attached to the plane structure picking up the front and rear spars and carrying at its forward end the mounting attachment fittings and which, as stated above, is the nacelle structure.

(i.) Engine Mounting

Assuming that the detail design is made up of a ring upon which the engine is bolted direct, the ring being retained in position by a system of struts which are attached at their rear end to the nacelle structure (see Fig. 2), the method of building up the unit could be on the following lines :—

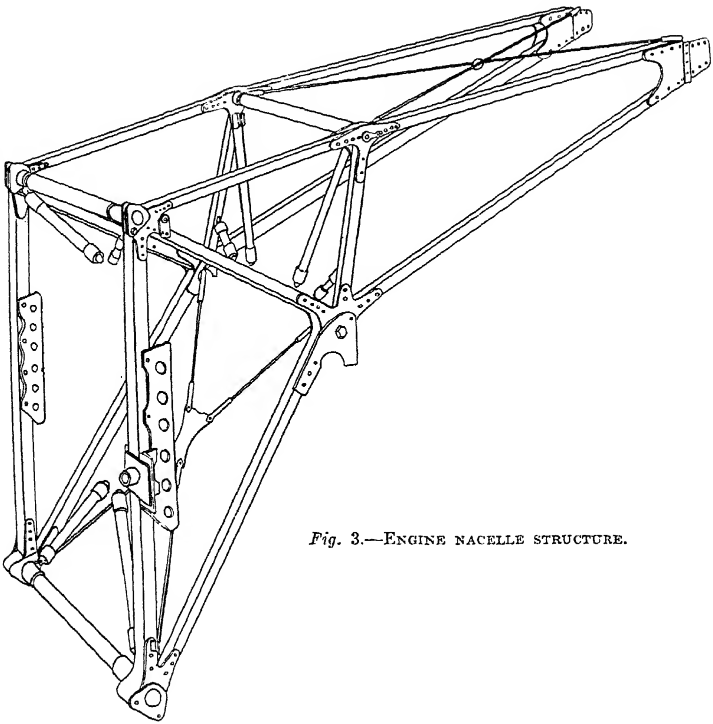


Fig. 3.—ENGINE NACELLE STRUCTURE.

The ring is completed, jig drilled for the attachment points, holes for the direct bolting of the engine being up to size, but those for the strut ends having a reaming allowance. The struts will be assembled in jigs correctly positioning the ends in their true angular relation. The final assembly fixture provides duplicates of the nacelle fittings on a base plate and pillars supported on the plate for setting up the ring relative to the nacelle fittings. The struts are now pinned at their rear ends on the nacelle fittings and the holes in the forward ends reamed in position with the ring and the bolts (taper) fitted.

(ii.) **Nacelle Structure**

For this unit the jig will correctly position the fittings for the front and rear spar attachment points and also those for the engine mounting rear end. Should the structure consist of square tubes and side plates (see Fig. 3), the struts and side plates will be jig drilled, the holes being up

to size except for the strut ends which pick up direct on to the fittings held in position by the jig. The holes at these points will be finally reamed in position.

(iii.) Nacelle Fairing

Tubular structure for the fairing will be assembled in welding fixtures following standard practice. The panels are shaped by press or other standard methods and the holes for the fixing clips drilled from a shroud plate.

B. LANDING GEARS

For a retractable undercarriage one form consists of each unit being made of two oleo struts with the wheel supported on a short axle carried from the lower ends of the struts. Radius rods deal with the fore and aft loads and are carried between the lower end of the oleo struts and a fixed point on the nacelle structure. The manufacture of the detail parts presents no special features beyond standard machine shop practice. The absorber unit assembly sets up the two oleo struts in their correct relation and the cross beams and bracing are then fitted, the holes for bolts being reamed in position to ensure that there is no slackness in the structure. Assembly jigs are now used representing the attachment points for the top ends of the oleo struts and the nacelle structure fittings for the radius rods. The oleo strut unit is placed in position, the radius rods fitted and bolted up, thus completing the unit.

C. CONTROLS—FLYING AND ENGINE

Flying Controls

The details of this component consist in the main of shafts supported on ball races for transmitting control loads where change of direction is necessary, a control column pivoted at its bottom end and carrying at the top the control wheel, pulleys along the line of cable runs to the tail end of the aeroplane, rudder pedals in the pilot's cockpit and push-pull rods in the planes out to the ailerons. Each of these sub-assemblies is comparatively small and requires very simple equipment to deal with jig drilling of details and assembly into their groups. With regard to the details themselves, machined fittings made from forgings or castings will require milling and drilling and in the case of the sheet metal parts these will be blanked and pierced and afterwards machine riveted together.

Engine Controls

A control box unit in the pilot's cockpit operates a system of push-pull and torque rods governing the throttle and mixture opening on the engine carburetter. The control box in the form of a casting will be milled and drilled on a fixture to ensure interchangeability and the forged levers jig drilled. A method of accurately setting up the torque rods for drilling

at the lever pick-up points is essential to enable the levers to be readily pinned on at their true angular positions. With regard to the other controls between pilot's cockpit and engines, these will be of the continuous type and present no special features in their manufacture and installation.

D. EQUIPMENT AND FURNISHINGS

Practically the whole of this group come under the sheet metal class and their production is based on the use of press tools and drilling jigs. The press tools can be of the form which are self-centering and require no setting up and the majority of the details can be handled in fly presses. The joining methods will be machine riveting or bolting.

E. FUEL AND OIL SYSTEMS, INCLUDING TANKS

Most of the pipes are of the flexible type and are made by firms specialising in this line. In the case of the solid drawn pipes of copper, aluminium or other suitable materials the work consists of bending to wire template (loading being necessary for severe bends) and expanding the ends to suit standard connections. Tanks are made up in various forms, one type having a welded-up aluminium shell with the baffles bolted in position. This class of tank will have the sheets pressed into shape and the welding assembly of the shell completed less one end. The tank is then thoroughly cleaned, tested for leaks under atmospheric pressure and afterwards cleaned and anodised. The baffles are then bolted into place, the second end welded on and the final test pressure applied. The tank is then completed by the application of the external protective treatment.

ENGINE INSTALLATION ON AIRSPEED ENVOY

By J. S. Watson

THE most usual power plant for the Envoy is the Armstrong Siddeley Cheetah IX, although quite a wide range of engines has been fitted. The engines are attached to mountings of welded steel tube construction, T.45 being the general specification. Most Airspeed mountings are of the flexible type, in order to lessen vibration in the air-frame and also to eliminate from the cabin a certain proportion of noise which would otherwise be transmitted through rigid members.

Flexible Mountings

Two forms of flexible mountings are used. In the first, the bolts attaching the engine to the mounting are housed in concentric rubber bushes. In the second, use is made of the " rubber in shear " type of bush, which takes advantage of the fact that the piece of rubber when subjected to shear forces will deflect by an amount several times greater than if the same force were applied in trying to compress the rubber, this being the same principle as embodied in the well-known " Lord " type of rubber bush as used on instrument board mountings.

In a flexible installation the object is to cushion the impulses set up by uneven torque, which are very pronounced when the engine is running slow or when rough spots are encountered at various speeds.

At the same time the airscrew must be held very steady in the fore and aft direction, as an appreciable movement in a direction normal to the plane of rotation might set up gyroscopic forces in the airscrew.

Therefore, the bushes are set in such a way that they are relatively " springy " in the direction of applied torque, *i.e.*, concentrically around the crankshaft, while being stiff in the fore and aft direction.

Maximum Movement Allowed by Rubbers

The maximum movement allowed by the rubbers is about $\frac{1}{8}$th in. measured in the direction of their axes, these being set tangentially around the crankshaft. Under normal running conditions the movement settles down to a steady deflection of about $\frac{1}{16}$ in. until the throttle opening is changed.

Under rough running conditions there is, of course, marked oscillation.

In the Airspeed design of this mounting, four bushes are used, one at each near corner of the structure at the points where it attaches to the centre section.

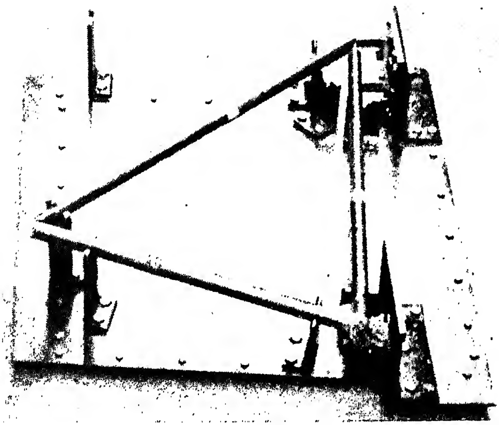


Fig. 1.—ENGINE MOUNTING.
Showing sub-assembly in jig.

With this design each part of the installation which is attached to the engine must be free to move. For instance, the cowling is carried on independent supports fixed to the mounting, and rides clear of the rigid airframe. On the other hand, if these rubbers were attached at the front ring of the mounting, other disadvantages would arise, as in the case of an engine-driven generator mounted on the rigid structure. In such a case great care would have to be taken to secure the least possible movement at right angles to the line of the drive.

Speed in Changing Engines

To the large operating companies, speed in changing engines is of great importance, the placing of the rubber bushes at the rear of the mounting means that only four bolts have to be withdrawn when "pulling" an engine.

It pays such companies to keep as spares complete power units attached to spare mountings, having all accessories assembled thereon, ready to be bolted on the aeroplane. Some Maintenance Departments even test run their engines in this condition, the complete unit, when coupled up to fuel, oil and electrical services, constituting almost a replica of the aeroplane's power plant. Recent Airspeed installations have been designed with this object in view.

Connections to the Engine

All connections to the engine except capillary tubes are broken where they pass through the firewall and are easily accessible. All accessories such as vacuum pumps, compressors, fluid pumps and generator, electric tachometer generator, filters, etc., are carried on the engine mounting; all connections between firewall and engine are interchangeable. Therefore when spare units, fully assembled, are available it is a very quick job to

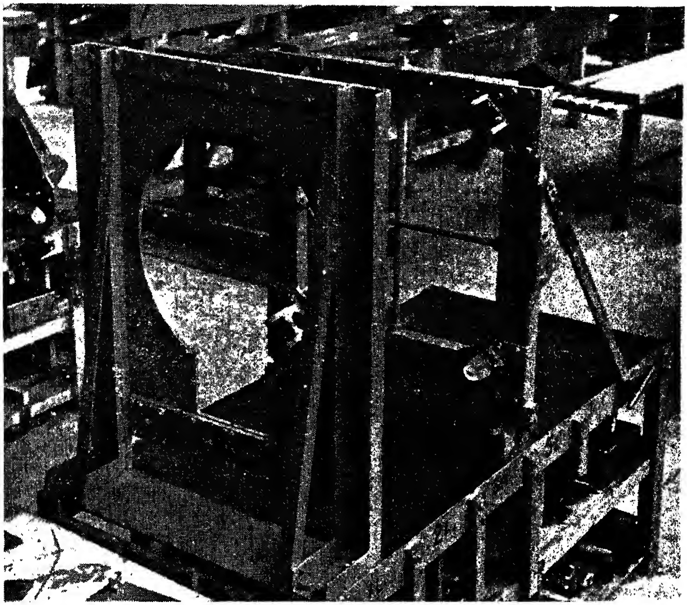


Fig. 2.—ENGINE MOUNTING JIG.

change units, entailing the withdrawal of only four bolts and the breaking of pipe lines and controls, etc., at the firewall.

Cowling

Use is made of either Townend ring, with small diameter after cowl, or N.A.C.A. type cowlings. The Townend ring type makes a very light compact cowl, taking up but a small proportion of the wing, but is used only with the smaller installations.

To cater for the larger engines, with their numerous accessories, the N.A.C.A. type is used, giving more room to enclose an elaborate installation. In some cases, where overall diameter of the engine is relatively great, the "helmeted" type of ring is used in order to make available more of the effective airscrew blade diameter. Pressure baffles are not fitted unless the cooling of the engine demands them.

The N.A.C.A. cowl is much heavier than a fairing of the Townend ring type, not alone because of increased area, but also on account of the necessity for adequately reinforcing the long chord ring itself, which is

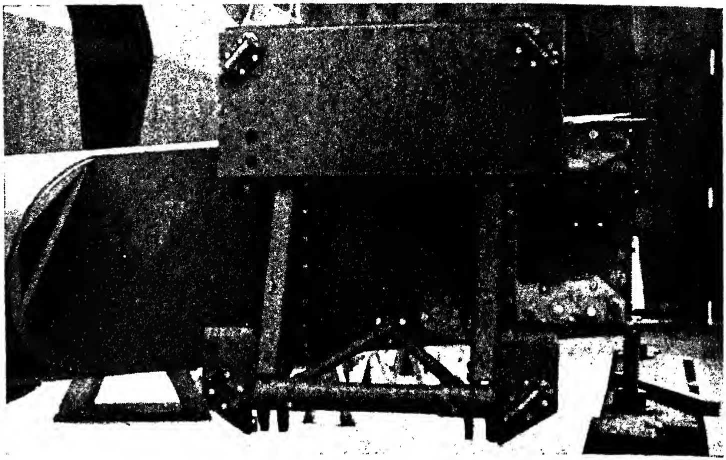


Fig. 3.—SHOWING FORK FITTINGS FOR ENGINE MOUNTING.
Note the four rubber bushes at rear.

subjected to severe air loads at high speeds which tend to make it slide forward.

For civil aeroplanes in places where it is easily workable "Electron" is largely used because of its lightness, but fireproofing regulations preclude its use in nacelles for military types.

Oil Systems

Each engine is fed independently from its own tank. Two systems are in use: In one the tank is located in the leading edge of the wing, the oil cooler, when necessary, being carried in the nacelle, air being led to it through a duct facing into the airstream. In the other system, where the nacelle diameter is greater, a combined type of tank and cooler is located in the nacelle.

When the leading edge type of tank is used, advantage is taken of the possibility of surface cooling in the following manner. The front of the tank is really a double skin. Scavenged oil from the engine is led into the top of the tank at one end. From this point a pipe extends across the length of the tank in the space formed by the double skin. This pipe is perforated with a series of holes along its length, facing forward, and the end of the pipe is blanked.

The pressure of the oil within the pipe forces it out in jets against the front of the tank, after which it runs down the cavity formed by the double shell. Thus, before hot oil has time to mingle with the general body of

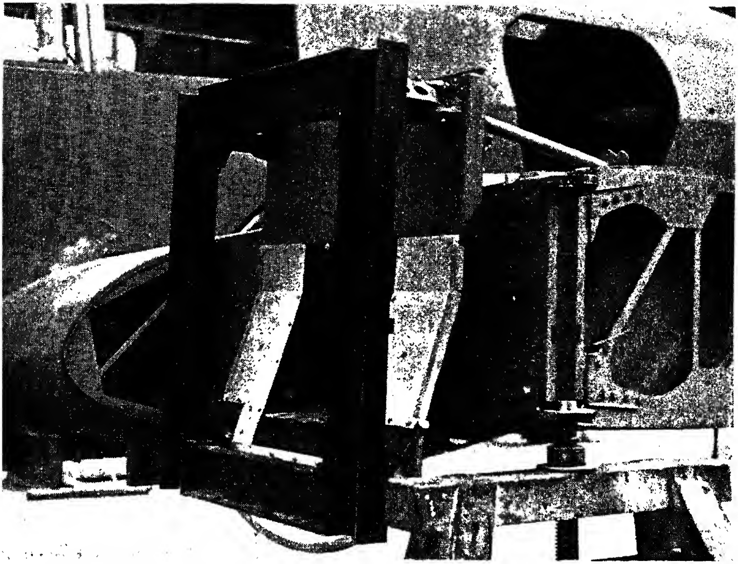


Fig. 4.—JIG IN USE FOR POSITIONING ENGINE MOUNTING ATTACHMENT FITTINGS. Showing part of fireproof bulkhead in place.

oil in the tank, it is forced into contact with the cold outer skin and some of the heat is quickly dissipated.

Within the tank is a small chamber called a " bye-pass compartment," through which the oil can be made to pass back to the engine instead of circulating through the main tank. This is used when warming up, and can be brought into action by means of a cockpit control. As soon as correct running temperature is reached the oil is once again passed through the main tank before being led back to engine.

Extra Cooling for Tropical Conditions

For aeroplanes operating in tropical conditions, extra cooling is necessary and for this the " Gallay " dual-stage cooler is used. This takes the form of a pair of compartments connected by a series of tubes, much as in the case of the automobile radiator. To prevent bursting of the pipes due to high pressures developed when the oil is cold and viscous ; a relief valve, set at a pre-determined pressure, allows the oil to pass directly from one compartment to the other and back to engine, without going through the tubes until warm. Cold air is blown across the tubes, and the oil in passing from one compartment to the other gives up its heat.

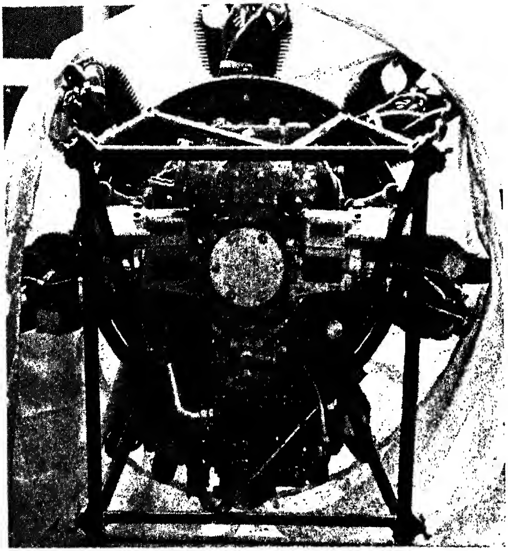


Fig. 5.—ENGINE IN FLEXIBLE MOUNTING.
Showing rubber buffers at rear corners.

The advantage claimed for the "dual-stage" type of cooler is that whilst previous types allowed the oil to congeal within the pipes in certain conditions, such as a long glide, with consequently a long period of "thawing out" after the throttle was again opened and cooling area needed, the dual stage cooler overcomes this difficulty.

Previous forms of this type had a bank of tubes all of the same bore, connecting the two compartments of the cooler. The bore was rather small and back pressure quickly rose when cold oil was circulated through them, this back pressure building up until the relief valve opened. When this happened, the oil already in the tubes tended to remain where it was and the blast of cold air passing across the bank of tubes "froze" the oil still further.

The "Dual Stage" Cooler

In the "dual stage" cooler several rows of tubes at the front end of the bank have a larger diameter than those behind, which form the majority. Even when the oil is relatively viscous, some of it will pass through these large diameter tubes, and any heat which is "wiped off" by the air blast serves to keep oil in the small diameter tubes behind from congealing, thus when the back pressure falls enough to close the relief valve again oil can circulate immediately through all the tubes.

Oil Circulation

To go back to the layout of the oil system, and referring to the surface-cooled tank, there are two different conditions which may be brought into action by cockpit controls.

First, when starting up, scavenged oil from the engine is led through

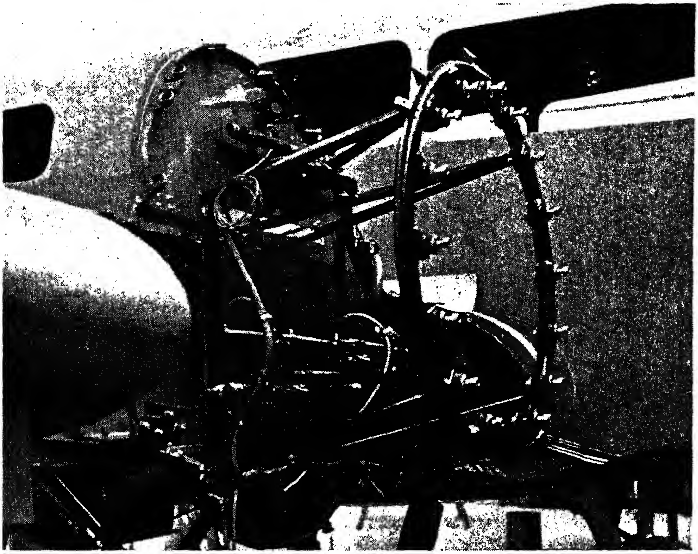


Fig. 6.—SHOWING RUBBER BUSHES AT FRONT OF MOUNTING.

the small chamber in the tank without being allowed to spray against the cold tank skin, and returns to the engine. When warmed up to operating temperature, the scavenged oil after entering the tank is sprayed against the cold shell, then circulates through the body of the tank, after which it goes back to the engine.

The change in circulation is accomplished by means of a bye-pass valve, controllable from the cockpit, this valve being situated in the line between engine outlet and tank.

When an extra cooler is used in this system, it is interposed in the line between bye-pass valve and tank, and comes into operation when the oil is allowed to circulate through the main tank, not while the flow is being bye-passed through the small chamber within the tank.

Combined Oil Tank and Cooler

In another Airspeed installation where the nacelle is large enough to permit it, a form of combined oil tank and cooler in one unit is mounted in the nacelle, cooling air being ducted to the cooler from a point between two of the engine cylinders, and exhausted at the trailing edge of the wing. In this unit the tank proper contains a small compartment as in the tank previously described, for short circuiting the oil when warming up. No

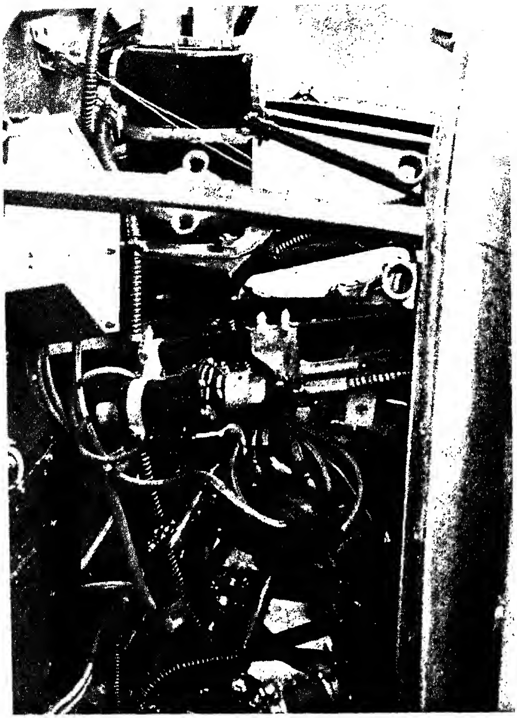


Fig. 7.—SHOWING INSTALLATION OF 500-WATT GENERATOR AND ELECTRIC TACHOMETER GENERATOR.

control is necessary for bringing either the cooler or the bye-pass compartment into operation, the action being automatic and dependent upon the viscosity of the oil.

The action is as follows : scavenged oil is led back into the upper compartment of the cooler. If hot it passes through all the pipes in the cooler to the lower compartment and thence into the main tank and back to engine. When scavenged oil is cold it is too viscous to pass through all the tubes. The pressure built up will then open the spring loaded relief valve and pass the oil straight into the small chamber within the tank and back to the engine and so it is quickly warmed up.

With this arrangement pipe-lines are cut down to a minimum and controls and bye-pass valves are not required. No part of the installation projects outside of the cowling, cooling air being admitted through a duct which extends forward between two of the engine cylinders, and is exhausted through another duct at the trailing edge of the wing.

Oil temperature thermometers are installed permanently in the inlet line to engine, but for flight trials readings are also taken of the outlet temperatures. Standard A.G.S. type pockets are used, the internal layout of these being such that the oil in its passage through the pocket is forced to " hug " the bulb of the thermometer all along its length, thus ensuring reasonably accurate readings; also the pocket is "jacketted," by means of a double shell, against temperature differences.

On civil aeroplanes a filter is installed when the engine-maker recommends it, in the inlet line, the mesh being 40 × 40 and is compulsory on military types.

Measurement of Oil Pressure

Oil pressure is measured either by the capillary type of gauge or the directly connected type, the advantage of the former being, of course, that if a break occurs either in the gauge or pipe line, oil pressure is not lost, only the transmitting fluid leaking out. The pipe-line in the case of the direct type is of tungum tube except where it joins the engine, where "Superflexit" is used, as also at the instrument board when the latter is mounted on rubber bushings.

Fuel System

Each engine has its own fuel supply. Normal Airspeed practice is not to interconnect port and starboard tanks or engines, on the grounds that such interconnection introduces the possibility of failure of the fuel flow due to either turbulence or a siphoning effect at junction points, or air locks, such faults being difficult to guard against in interconnected systems. The more straightforward the system the less chance of failure.

The supply of fuel for each engine is contained in a main tank hung by straps in a compartment in the centre section of the wing between fuselage and engine, and, if required, auxiliary tanks in the extension planes.

The suspension methods of mounting these tanks is a considerable time saver when withdrawal is necessary, it being only necessary to undo the straps to drop the tanks out, detachable doors being fitted underneath and forming the bottom surface of the wing.

The tanks are constructed of aluminium, the shells being welded and the baffles bolted by special bolts to the shells. The sumps are removable and are made of tinned steel, the pipe connections being welded.

Fuel capacity gauges are of the Smith electrical type.

When auxiliary tanks are used these deliver into the main tanks by gravity, *viâ* a cockpit controlled cock and a non-return valve. They are not brought into operation until an equivalent amount of fuel has been taken from the main tank, due to the auxiliary tank having a slight amount of head over the main tank.

The junction with the latter is at a point remote from the outlet to engine to avoid any possibility of complication arising from turbulence between two flows. From the main tank outlet fuel is sucked by the engine pumps. Thus the system is not in any sense a "combined" one of pressure pump and gravity, but depends on engine pumps alone to deliver fuel to the carburetter.

For doping the cylinders before starting a pump of the Ki-gass or R.A.E. type is used, sucking fuel from a low point in the system. With the Ki-gass type usual practice is to fit a cock in this line between engine and

Ki-gass priming pump to safeguard against the consequences of the pump being left "open," *i.e.*, the handle not being screwed home after use, as this might result in fuel being sucked into the cylinders *viâ* the pump by induction, so causing an excessively rich mixture.

In accordance with fire-proofing requirements, a cockpit controlled cock is placed in the line from main tank to engine aft of the fireproof bulkhead.

Another cock, also controlled from the cockpit, is located between auxiliary and main tanks. The tank vents are connected to a common pipe. This is to avoid having unequal air pressures in the tanks such as might be present if the tanks had individual vents. Such a condition has been known to result in a building up of fuel in one tank and a rapid lowering of level in the other, due to the fuel tending to run into that tank in which the air pressure was lowest.

In order to get a positive pressure in both tanks former practice was to face the vent pipes forward into the air stream. However, this sometimes resulted in iced-up vents, the pipe in such a position forming a ready trap for sleet or rain.

In order to avoid this condition and at the same time preserve the positive air pressure, Airspeed practice is to enclose the mouth of the vent pipe within a venturi, the larger orifice of the venturi facing forwards, while the pipe has its mouth facing aft. Thus there is little possibility of the vent becoming blocked except in the very unlikely case of the whole venturi being iced up and a positive pressure is maintained by reason of the venturi effect.

WOOD MACHINING IN AIRCRAFT CONSTRUCTION

By C. Stredwick, *de Havilland Aircraft Co.*

THE chief timber used in wooden aeroplane construction is Sitka spruce which grows in the belt of timber forests running from Oregon, in U.S.A., to Alaska, on the Pacific Coast line. It is brought into the factory in huge planks or bulks, some of which are 40 ft. long by 10 in. wide by 6 in. thick. After the timber has been unloaded from the lorries it is carefully selected and neatly stacked in the timber-drying sheds.

These stacks (Fig. 1) are built up to the height of the shed and about 3 to 4 ft. wide. Between each layer of planks sticks 1½ in. square are carefully placed at intervals of approximately 5 ft. to enable the air to circulate all round the planks. The sheds are made up of sliding sections for easy access to the timber. Each section is made of battens spaced at intervals of about 2 in., thus ensuring a perfect current of air throughout the shed. The timber is left there for a period of eighteen months (or more if necessary) to season.

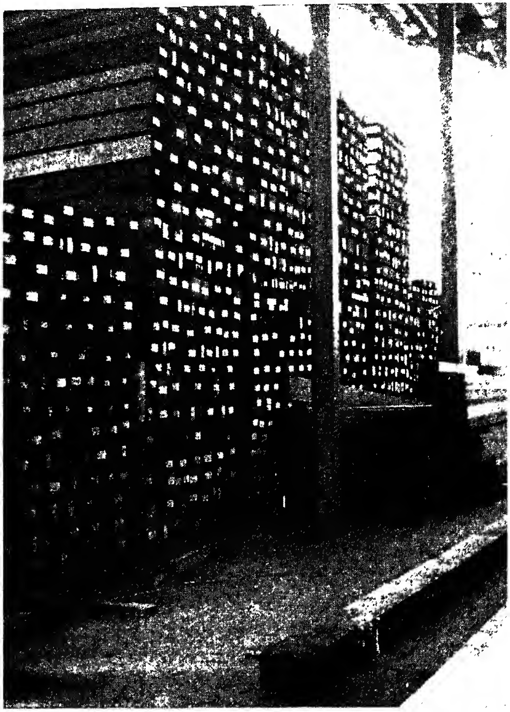
During this time the stacks should be pulled down at least once and the timber thoroughly examined for rot, for if one plank is affected it might easily spread throughout the whole stack. When restacking the timber it is best to put the planks that were on the bottom of the stack at the top and *vice versâ*, as there is a much better and warmer current of air at the top of the shed than at the bottom. It is not always possible to wait for so long a period before the timber is needed for manufacture, so the drying is done artificially in drying kilns by means of steam and cool-air fans.

By this means all the free moisture is extracted from the cells of the wood and part of the hygroscopic moisture from the cell walls. The amount taken is determined by the condition in which the timber is needed for manufacture. (Hygroscopic moisture is the moisture held by the cell walls after the free moisture has left.)

Assuming the timber is properly seasoned, it is taken from the stack and conveyed into the saw-mill, where, after a thorough examination for knots, curls and other defects, it is cross cut into the required lengths.

Cross Cutting the Timber

The operation of cross cutting is done on a suspended cross-cutting machine (Fig. 2). The main frame of this machine is carried on hinge pins from hangars which are suitably fixed overhead. An automatic counter-balance is fixed to the swinging frame to bring the saw to the



1.—PLANKS IN DRYING SHED.

back position after having made the cut. The speed of the saw spindle is 1,000 r.p.m., and the saw used is about 36 in. in diameter and will cut timber up to 18 in. wide by 7 in. thick. From each plank a piece 6 in. long is cut from as near the centre as practicable, which is sent to the laboratory and tested for moisture content, density and fibre value.* The lengths of timber are stacked behind the circular saws to await the results of the tests.

When these are received the lengths of timber are converted on a circular saw bench (Fig. 3) into spars, interplane struts, longerons and fuselage members, etc., sufficient material being left on to allow for planing. To do this the operators must have a thorough knowledge of timber conversion, suitable for aeroplane construction, for here all visible defects, such as strong and hard growth, gum pockets, etc., are cut away without too much waste of material. The number of annual rings to the inch must be observed, as any part of the plank that has more than six annual rings to the inch must be cut away. The plank must also be examined for spiral or cross grain.

The maximum inclination of the grain to the length of a member must not exceed 1 inch in 15. If the grain exceeds this limit, a line is

* The timber which does not pass the test (as laid down by the Air Ministry), for stress members, is used up for subsidiary parts and if any fails altogether it is used for jigs and patterns.

drawn diagonally across the plank at such an angle that will bring the grain within the required limit. The operator, sawing to the line, cuts off a wedge-shaped piece of material and from the freshly cut face of the plank produces the members (see Fig. 4). This necessitates a certain amount of waste material, but were this not done all the members cut from this plank would be scrapped by the timber inspector and much valuable time and material would be wasted.

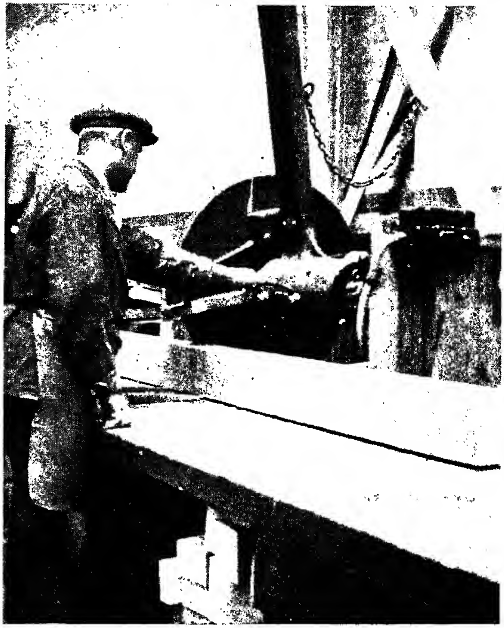


Fig. 2.—Pendulum or suspended cross-cutting machine.

After being cut, the members are neatly stacked in a similar manner to the bulk timber (see Fig. 5), but in another shed at a temperature of, if possible, from 60° to 65° for further conditioning. The result of the moisture test taken from the planks determines the period of stacking for the scantlings, but this would not be longer than two or three weeks.

Hand Planing and Jointing Machine

When the mill foreman is satisfied that the scantlings are fit for working they are conveyed into the wood mill to the hand-planing and jointing machine to be straightened and squared up. This machine has a circular cutter block 5 in. in diameter, with two cutters protruding about $\frac{1}{16}$ in. beyond the circumference of the block (see Fig. 8), and revolves at a speed of 4,000 r.p.m. The scantling is planed by passing it along the table of the machine and over the cutters by hand, thereby planing out any bumps or hollows in the timber.

The true face is then held against an adjustable fence set at right angles to the cutters, squared up and straightened in the same manner

Fig. 3.—CIRCULAR SAW BENCH.
The operator is converting plank into spars.

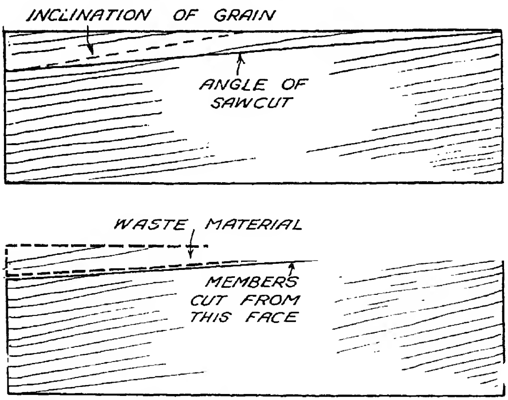


Fig. 4.—THE MAXIMUM INCLINATION OF THE GRAIN TO THE LENGTH OF A MEMBER MUST NOT EXCEED 1 IN 15.

(Fig. 6). This must be accurate, as every other operation depends upon the straightness and squareness of the member.

When this has been satisfactorily done the member is passed on to a panel planer or thicknessing machine. This has a square cutter block which rotates at approximately the same speed as that on the former machine. The table has a vertical adjustment by a hand wheel and screw. An index scale at the side of the machine indicates the thickness at which the machine is planing. The member is fed into the machine (Fig. 7) between the table and the revolving cutters by grooved rollers and fed out of the other end by plain rollers.

After the member has been brought to the required width

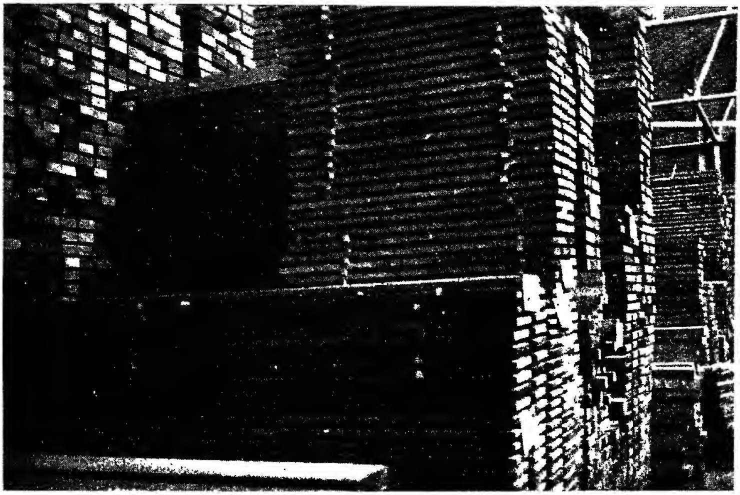


Fig. 5.—SCANTLINGS IN DRYING SHED AFTER CONVERSION.

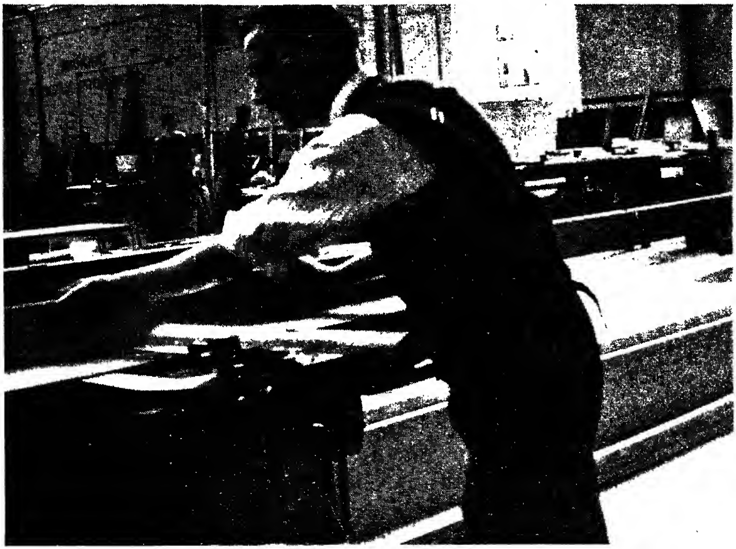


Fig. 6.—SQUARING UP SCANTLING.

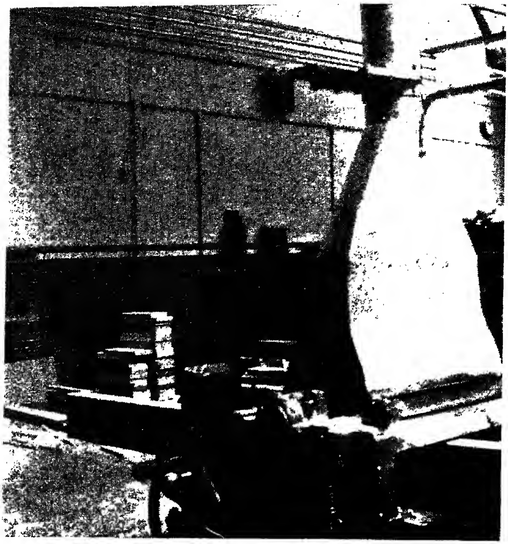
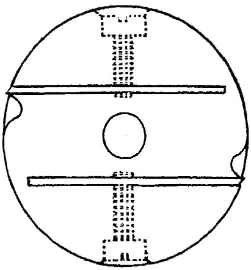


Fig. 7.—Spar passing through thicknessing machine.

and thickness by this method, it is submitted to the timber expert, who examines it to see if there are any defects which have been disclosed during the operations of machining. The inspector having satisfied himself on the visual examination affixes a serial number to the member, from which a short end is cut and tested for moisture content, density and fibre value.



ig. 8.—Circular cutter block.

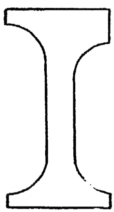
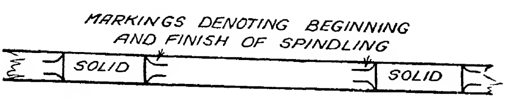


Fig. 9.—H section.



10.—Method of setting out markings for machining.

The Spindling Operations

Assuming the member to be a spar, when the result of the tests is known the spar is taken to be set out for the spindling operations. These are set out on one edge, about six at a time, from a rod which has the necessary markings showing the position where the machining is to commence or stop. See Fig. 10 for method of setting out.

Great care must be taken over this,

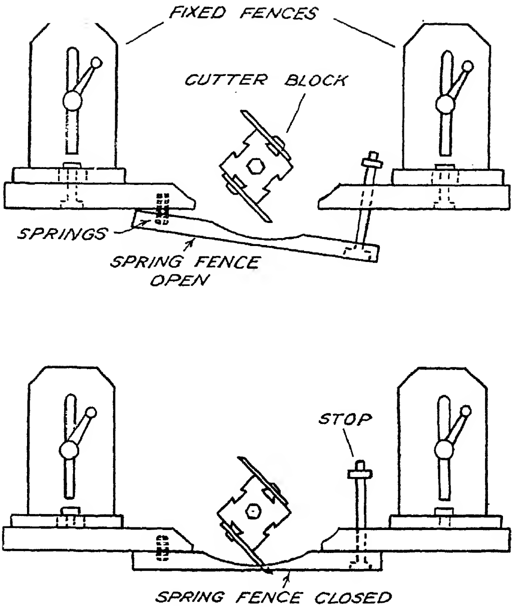


Fig. 11.—DETAILS OF SPRING FENCE.

as it is sometimes necessary that small curls or other minor defects should be kept in the solid part of the spar, as marked by the timber inspector. When this is done it is conveyed to a Sagar vertical spindle moulding and shaping machine for machining to the H section (see Fig. 9). The spindle has three speeds, *i.e.*, 3,000, 4,500 and 6,000 r.p.m.

For this operation a square cutter block is used, which when machining revolves at 4,500 r.p.m. (Some operators prefer the use of what is called the French spindle, described later in this article.)

The Spring Fence

The block is held firmly on to a vertical spindle head by means of a nut at the top. Two high-speed steel-faced cutters are firmly bolted on to opposite sides of the block to the required width of the cut which is to be made (Fig. 11). Two independent fences are firmly held to the table of the machine by vee slides, and to these fences a spring fence is hinged and set to the correct position for machining the depth of the cut. (The spring fence is a safety guard.)

Two lines are marked on the face of the spring fence, one on the left-hand side, where the cutters commence to protrude through the fence, and one on the right where they run out. To commence the operation of spindling, the operator holds the spar against the face of the spring fence, with the bottom edge of the spar on the table of the machine, and with the line marked on the top edge of the spar denoting the commence-

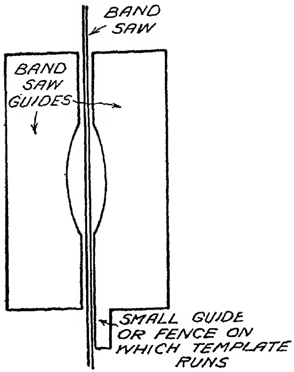


Fig. 12.—When using a template a small guide or fence is attached to one of the saw guides.

ment of the spindling, directly in line with the left-hand marking on the fence.

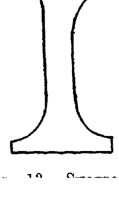
Then he slowly swings the spar forward on to the revolving cutters until it reaches the full depth of the cut, then propels it along the table, at the same time holding it hard against the fence.

The speed of cutting depends upon the individual, and when getting to within $\frac{1}{2}$ in. of the line denoting the finish of the cut the operator diminishes cutting speed and slowly brings the line marked on the spar denoting the finish of the spindling to the line marked on the *right*-hand side of the fence.

When the H section of the spar is completed it is conveyed to the bandsawing machine. This machine has two saw pulleys 30 in. in diameter on which an endless saw runs. The saw is approximately 16 ft. long, and the speed of the driving pulley, which is at the bottom, is 750 r.p.m. The table of the machine is mounted on a quadrant for canting. The bandsaw will cut *any* profile, the operator working to a pencil line or to a template which is bradded to the member.

When using a template a small guide or fence is attached to one of the saw guides, and the profile is cut by running the template along the small guide, past the saw (see Fig. 12), enough material being left on the member to allow for cleaning up on the spindle. By this method marking out is eliminated.

After the tip has been roughly profiled on this machine the spar is taken to the dimension saw, where it is cut to length. Here all members, from the largest spar to the smallest packing block (some of which are only $\frac{1}{2}$ in. in length), are cross cut to a perfect length, ready to drop into the assembly jigs without the necessity of any hand work whatever.



The spindle speed of the machine is 2,000 r.p.m., and the table is divided into two sections. The left-hand section travels parallel with the saw on ball-bearing runners for cross cutting and can be locked in position when the travelling motion is not required. An angle fence is mounted on the running table when cross cutting, which can be set to any angle (see Fig. 14). Against this fence the spar is firmly held and the root

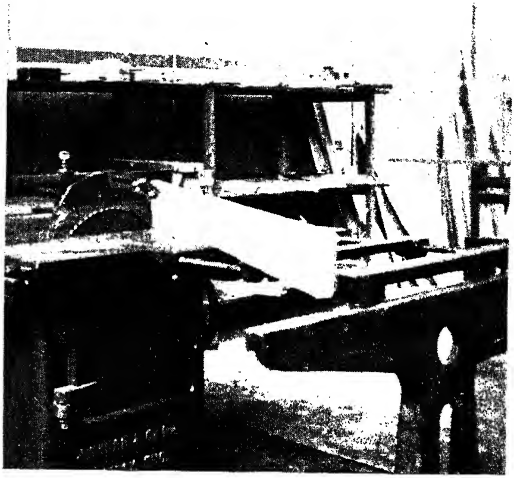


Fig. 14.—DIMENSION SAW BENCH.

Sliding section is in foreground. Fence is set to approximately 38 degrees.

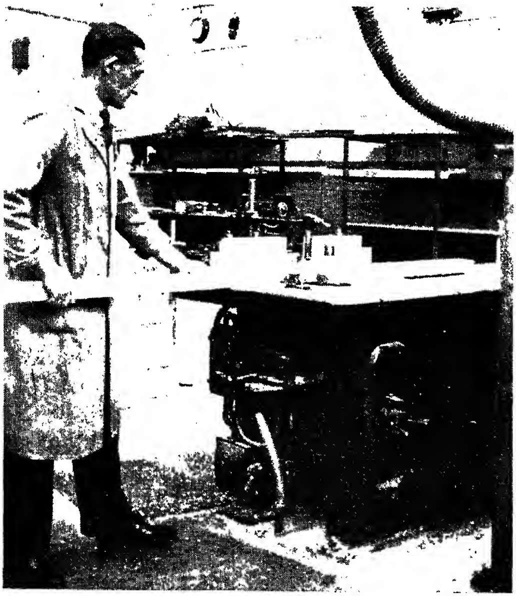


Fig. 15.—METHOD OF BEVELLING SPAR.

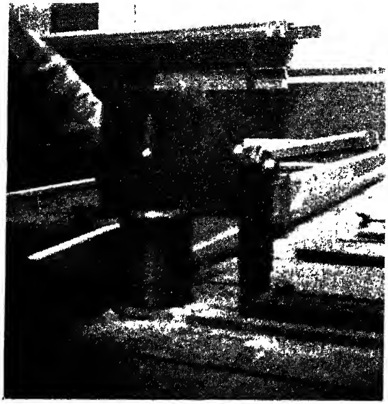


Fig. 16.—METHOD OF PROFILING TIP-END OF SPAR. Two rings can be seen. The jig is mounted on bottom ring.

end is cut to the finished length by propelling the table along until the saw has cut through the wood.

In this instance, owing to the length of the spar, the operator cuts to the overall line, which is marked on the spar by the setter out, but in the case of shorter members these are all cut to a stop which is attached to the fence. While the operations of bandsawing and cross cutting are being done, the spindle moulder is being set up for bevelling the top edge of the spar.

Two bevelling cutters are bolted on to the cutter block and the two independent fences are set in such a position that will enable the spar to pass between them and the cutters (see Fig. 15), thereby bringing it to the finished width while bevelling.

The spar is usually planed up $\frac{1}{16}$ in. over size to allow for any shrinkage that might occur after having been planed, and as all measurements are taken from the bottom edge of the spar any surplus timber is cut away

Fig. 17.—SLOTTING ROOT END OF SPAR USING SPINDLE WITH SAW ATTACHED.

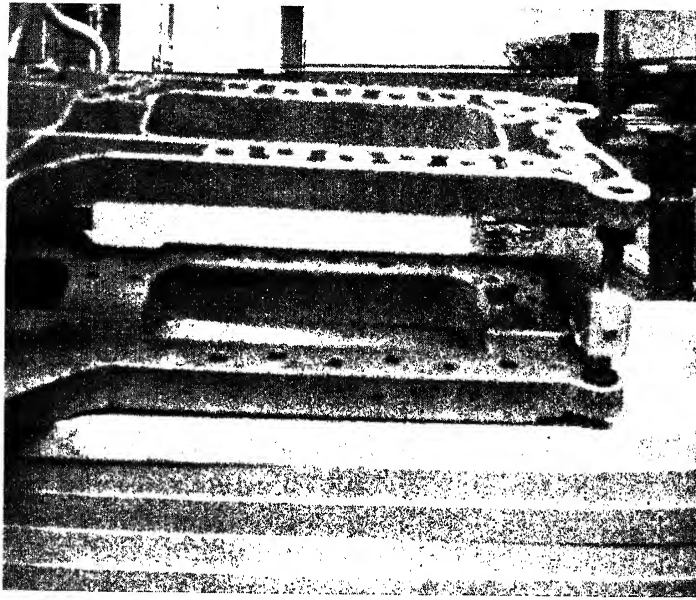


Fig. 18.—SPAR DRILLING JIG.

when it is being bevelled (see Fig. 13, showing section of spar after bevelling). The spar is held down on to the table of the machine, against the fences, by pressure springs.

Profiling the Tip End of the Spar

The next operation is the profiling of the tip end of the spar. After the fences, springs and cutter block have been dismantled, a circular cutter block is adjusted to the spindle head and two rings are firmly bolted on to the table, one being mounted above the block and one underneath ; this is to enable the operator to machine the spar with the grain of the timber. If only one ring was used the spar would have to be worked against the grain on one edge, the result being a rough finish. The rings are set about $\frac{1}{64}$ in. forward of the circumference of the cutters.

When these are correctly adjusted, a spindle pad or template, profiled to the finished size of the tip, is bradded on to the spar. One edge of the tip is profiled by holding the pad against the top ring and propelling the spar past the revolving cutters (Fig. 16) ; it is then turned over and machined in a like manner with the pad held against the bottom ring.

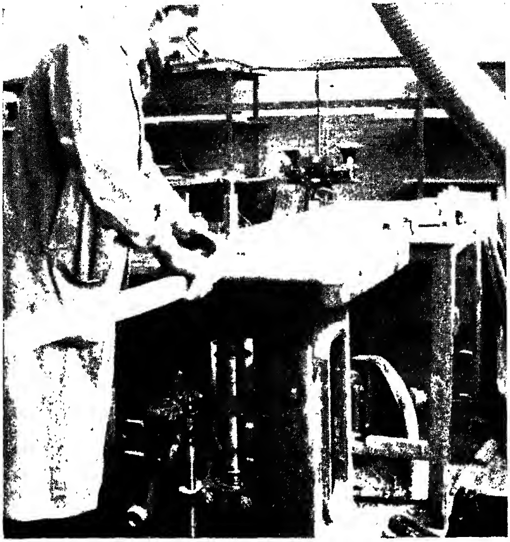


Fig. 19.—SPINDLING BEND WITH FRENCH SPINDLE HEAD.

The final spindle operation is the slot in the root end, into which the metal fittings are bolted.

For this a circular saw is used, which is fixed to the spindle head in a similar manner tothe cutter blocks. A shallow fence is bolted on to the table and set to the correct position for cutting the depth of the slot.

The slot having to be cut at an angle of 9°, a jig is necessary, upon which the spar is laid. The operator holding the jig against the fence propels it along the table past the saw (Fig. 17). The spar is next transferred to the drilling machine for the operation of drilling the bolt holes. All holes are jig drilled, the jigs being constructed to enable the spars to be drilled from both sides, each hole meeting accurately in the centre of the spar.

In Fig. 18 is a jig of the type mentioned. Great care is taken over the drilling, for the holes must be perfectly true, otherwise great difficulty would be found in the assembly of the fittings and the spar would in all probability be scrapped. It is now conveyed to the detail inspector, who checks all measurements and examines it to see if any defects have been disclosed during the operations of machining.

If all is satisfactory, the inspector affixes his stamp and the date, and the spar is sent into the wood detail department to have the packing blocks glued and screwed on. Apart from the fixing of the packings, the spar is machine finished.

The Cantilever Spar

The different operations necessary for the production of the cantilever spar will now be described. The preparation of the timber is exactly the same for this as it is for the H section spar. If the flanges of the spar are exceptionally large, they are built up with three or four laminations,

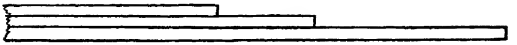


Fig. 20.—METHOD OF LAMINATING.

each lamination being given a serial number by the timber inspector, and each piece being tested. They are then conveyed into the wood detail department to be glued together, after which the member is sent back to the mill, where it is squared up on the planing machine.

Then it is sawn diagonally across from end to end, thereby producing two flanges. This procedure is not always possible where the flanges are over 16 ft. long and a large production wanted, as great difficulty would be experienced in finding sufficient lengths of grade A timber.

To overcome this, the flange may be laminated with timber of different lengths (see Fig. 20). This has its advantages inasmuch that it helps to use up the short ends of the bulk timber that accumulate during the breaking-down period.

After having been roughly tapered on the circular saw, the flanges are sent to the thicknessing machine to be planed to the finished size. To do this a tapered planing board is used. The flange is laid upon the planing board with the rough sawn face up and the thickest end of the flange at the thin end of the board, making the whole parallel, and then fed into the machine.

From the planing machine it is sent to the spindle moulder for bevelling and from there to the dimension saw to be cross cut to the finished length. Then it is taken to the detail inspector for checking and stamping, after which it is brushed with a thin coating of glue to check any development of shakes and sent to the stores.

The Production of the Interplane Strut

Again the timber process is exactly the same as before. From the timber inspector the necessary timber is conveyed to the dimension saw for cross cutting to the finished length, a short end being kept for test purposes. When the test results are received, the ends of the strut are roughly tapered and then taken to the spindle moulder. Here the ends are profiled by means of a jig, working with the circular cutter block and rings. The next operation is the machining of the leading edge. The square cutter block again comes into use, on to which two cutters, ground to the leading edge, are bolted.

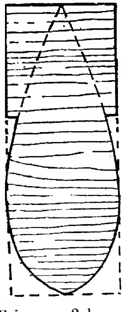


Fig. 21.—SECTION OF STRUT.

Showing cut taken well into trailing edge section.

The two independent fences are adjusted, against which the operator holds the strut while propelling it along the table past the revolving cutters, leaving a section as shown in Fig. 21. Note that the cut has been

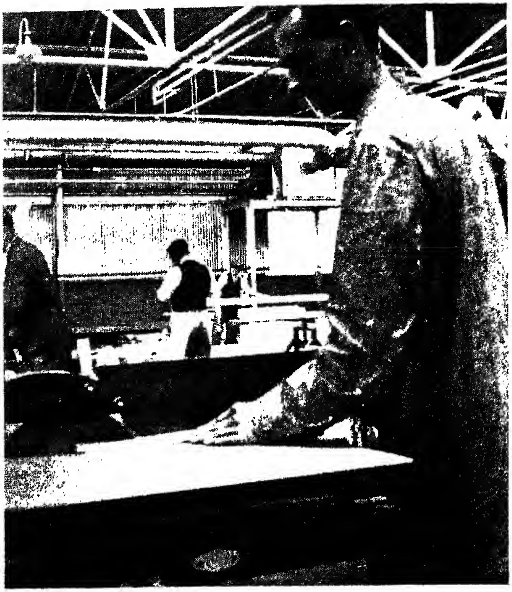


Fig. 22.—SAWING SHAPED RIB.

taken well over the centre line of the strut.

This is done to eliminate any possibility of a ridge being left in, which would occur if the cut were taken only to the centre line. The final operation is the machining of the trailing edge. The cutters are removed from the block and two more ground to the trailing edge section are bolted on and the member is passed by the cutters as before. It is then inspected and stamped ready for delivery to the stores.

Previous paragraphs indicate the different operations necessary for the production of main plane spar and interplane struts. The following describes the method for smaller members, *e.g.*, a main plane rib. The material needed for the cappings, slattings, blocks and webs, is selected from the off-cuts and short ends of timber that accumulate during the conversion of the larger members.

The Machining of the Cappings and Slats

These are sawn up by the circular saw to the required size and taken to the four-cutter moulding and planing machine. This machine is used for all kinds of small sectioned members such as rib cappings, slattings, stiffeners, leading edges, etc., where large quantities are required. It has four cutter heads, each revolving at 4,500 r.p.m.

One horizontal cutter head is at the feeding-in end of the machine, revolving just below the surface of the table, two vertical heads, one on either side of the machine, which are carried on vee slides for horizontal adjustment, and the fourth running horizontally overhead at the feeding-out end of the machine.

After the operator has adjusted and bolted the necessary cutters

on to the blocks and set the machine, the capping in its rough state is propelled through the machine by grooved rollers. Each cutter head has its own particular job to do; the first planes one side of the capping, the two side cutters each plane and slightly radius the edges and the top cutter planes and grooves the other face, ready to take the rib web (Fig. 23).

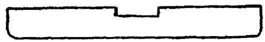


Fig. 23.—SECTION OF CAPPING.

When the cappings are finished the grooving cutter is removed from the overhead block and replaced by a square one, and the slattings are machined up in the same manner, after which both are put into a convenient rack until the other parts of the rib are completed. The rib webs are produced from short ends of material which are thick enough to cut five or six webs after they have been profiled on the spindle.

These ends are conveyed to the bandsawing machine, where the webs are profiled by means of a template, using the small guide as described previously in this article. They are next taken to the spindle moulder, and after being cleaned up by means of the circular cutter block and rings, they are conveyed to the dimension saw.

Here they are ripped up (Fig. 22) to the finished thickness and cross cut to length. In the meantime, the material for the packing blocks has been planed up and sent to the dimension saw and is now machined up to the necessary profile. The cappings and slats are collected from the rack and the complete rib is conveyed to the detail inspector to be passed before being sent into the wood detail department for assembly. All members which have to be profiled are machined on the spindle moulding machine.

The French Spindle

When a square section is called for the circular block and rings are used, but for members such as wing tip bends, circular window mouldings, etc., the French spindle head is needed.

This can be fixed to the machine in place of the head used for the square and circular cutter blocks. It is made of nickel steel and has a vertical slot through the centre for holding flat cutters. The cutter is firmly held in the slot by the centre screw. The diameter of the spindle

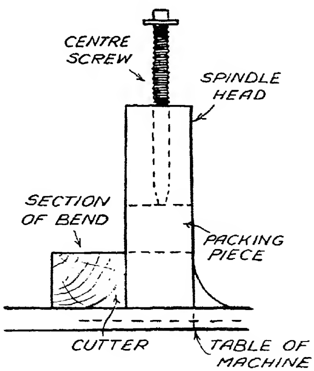


Fig. 24.—SHOWING CUTTING EDGE UNDERNEATH MEMBER.

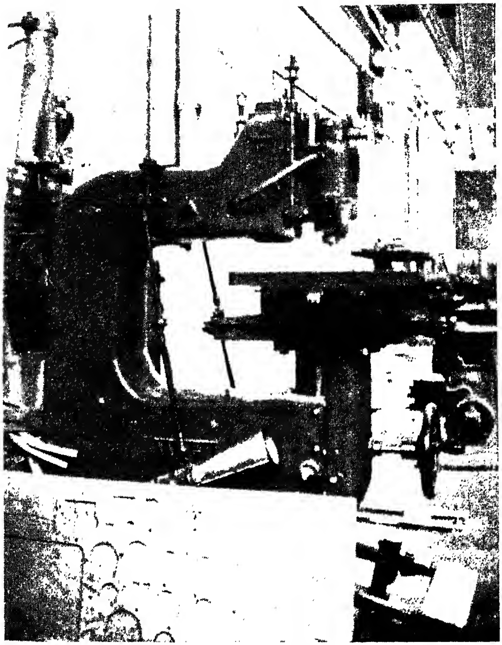


Fig. 25.—ROUTING AND RECESSING MACHINE.
The template can be seen in the foreground.

head varies from 2 in. to $\frac{3}{4}$ in. in diameter.*

To profile the member the rings are used in the same manner as for the circular blocks. When wing-tip bends or curved leading edges, etc., are sectioned they are held directly against the spindle head (Fig. 19). The cutter is made so that the cutting edge is underneath the member, as there is less likelihood of the operator cutting himself than if the cutter was revolving on the top (Fig. 24).

Wood machining is a dangerous occupation, and all precautions must be taken to see that all cutters and saws are carefully guarded to prevent, as far as possible, any accident happening to the operator.

All irregular-shaped parts, such as ply gussets, ply coverings, etc., are profiled on a routing, carving and recessing machine (Fig. 25). This machine eliminates setting out, with the exception of the necessary marking out necessary for the making of any templates or jigs that are required.

The spindle, with its motor, is mounted on vee slides, and has a vertical movement which is operated by a foot pedal, and has two speeds,

* When using this type of spindle head a speed of 6,000 r.p.m. is used, on some spindle moulders even more, for the faster the cutter revolves the easier the cut. The type of cutter used is made of silver steel and to sharpen it the operator uses a very fine-cut Swiss file. When a keen cutting edge has been obtained it is turned over with the aid of a burnisher, thereby forming a burr with which the wood is cut.

i.e., 18,000 and 24,000 r.p.m. A pin is positioned in the centre of the table for use when working irregular shapes or with jigs and a cutter is adjusted to the spindle head directly over and in line with the pin.

To produce the gussets a template or replica of the gusset is mounted on a board made just a little larger than the template. The template is turned face down on to the table of the machine and the ply needed for the job is bradded to the opposite side of the board. The template is then held against the pin in the table, the spindle head is brought down by means of the foot pedal until the cutter is in contact with the wood, and the gusset is profiled by working the template round the pin while the cutter is brought down deeper into the wood until it is cut through.

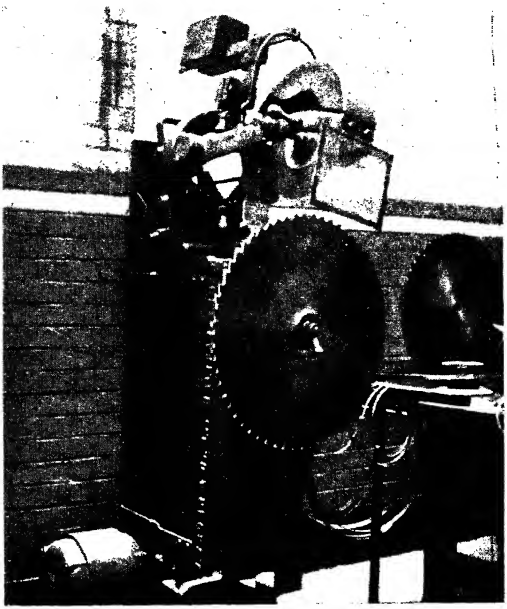


Fig. 26.—SAW SHARPENING MACHINE.

Spruce ribs that have to be lightened, instrument boards or any members in this category, are produced on this machine.

The Circular Saw Sharpening Machine

Fig. 26 shows the circular saw sharpening machine. A balanced arm carries the grinding wheel and can be swivelled to any desired angle. It is brought down to the saw by hand and a stop is used by which the teeth are kept to a regular shape and size. Fig. 27 shows us an automatic bandsaw filing and setting machine. A disc crank and connecting rod operates the file backward and forward past the teeth, sharpening the teeth on the forward movement. A lifting arrangement is provided on

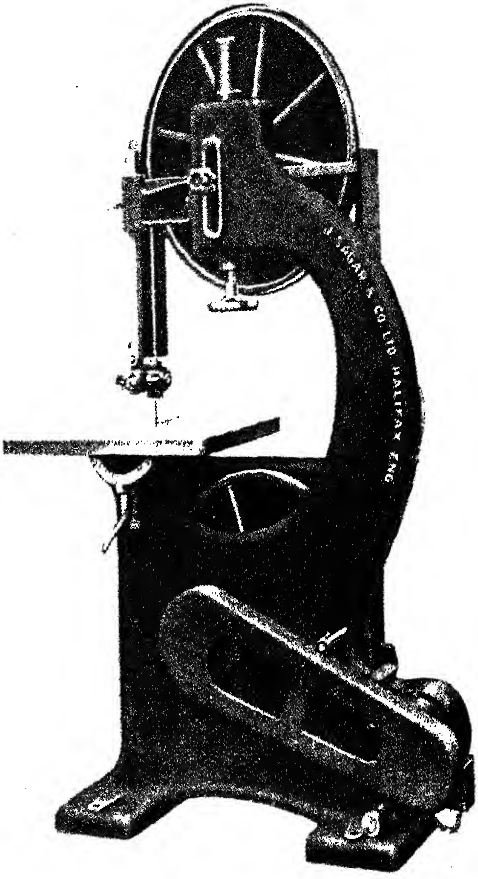


Fig. 27.—AUTOMATIC BANDSAW FILING AND SETTING MACHINE.

the backward movement similar to hand filing. The saw is propelled by a pawl which is actuated by a cam. The setting hammers are arranged one on each side of the saw and are actuated by cams and springs. After the teeth have been fed forward the hammers strike the teeth alternately and an arrangement is provided for varying the amount of set.

This machine is very useful, inasmuch that it can be left while the operator attends to other work. The spindle cutters and planing cutters are ground on a cutter grinding machine. For grinding planing cutters a holder is provided which works on guideways across the face of a cup emery wheel and which can be adjusted to give the required bevel on the cutting edge.

MONOSPAR WING CONSTRUCTION

By L. C. Williams, *Assistant Designer, General Aircraft Ltd.*

THE monospar system was developed as a method of providing a light monoplane structure. Before describing the system it may be of interest to deal briefly with the loads which act on the airframe.

Wing Loads

The lift and drag of a wing vary with the speed of flight. As the speed increases the lift moves back along the chord. If the resultant lift always acted through the same point on the wing it would be unnecessary to have more than one spar, since the spar could be placed over the centre of pressure. Drag could be taken through a beam lying in the plane of the wing.

As it is, if an aeroplane is dived and then pulled up sharply, the lift, which at the commencement of the pull-out is acting at 40–45 per cent. of the chord from the leading edge, moves forward until it is at less than 30 per cent. of the chord as the aeroplane cushions into the air at a large angle of incidence. This change of location of the centre of pressure causes a large change of torsion which has to be transmitted through the wing structure to the fuselage and neutralised by an approximately equal and opposite torsion from the stabilising tail load on the tail unit.

In aeroplanes built for violent manœuvres even larger torsion loads may be experienced in the faster dives, the centre of pressure moving aft and the torsion building up as the diving speed is increased.

The Biplane

The lightest and stiffest structure for taking the varying load which is exerted by the air was, for many years, the biplane. Two spars were installed in each wing, interplane struts connected the two front spars and two rear spars out towards the tip and again in the centre section and all sides of the box were braced with wires.

Aerodynamically the external struts and wires of the biplane were bad since they produced drag and interfered with lift. The biplane wings were inefficient since a great deal of area was screened by the fuselage and did not produce their full lift and profile drag was large, due to the multitude of fittings required for the wire bracing.

The Monoplane

The monoplane wing was free from protuberances. For equal aspect ratio and induced drag the wing was thicker and provided easier

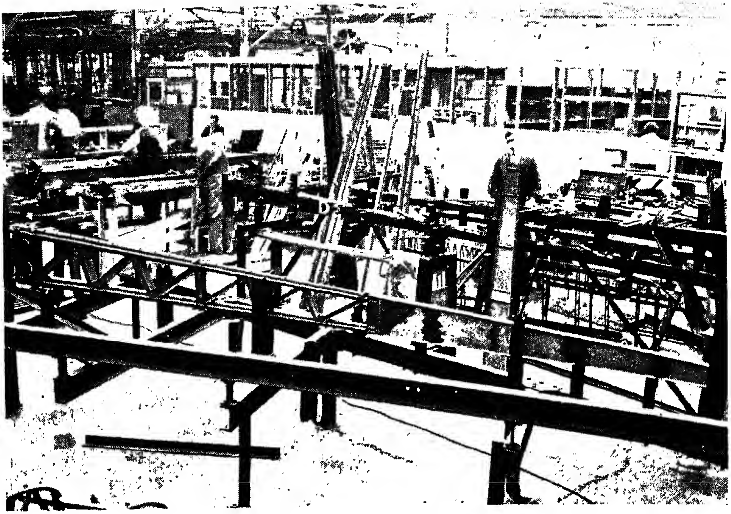


Fig. 1.—The single wing spar jigged for assembly.

housing of engine nacelles, and, when it came, the retractable undercarriage.

The pilot's view was immensely improved since the blind area was limited to but one wing instead of two.

The monoplane by comparison with the biplane was cleaner, and for equal weight, faster, but since the wing spar had now to be enclosed in one wing instead of having a height equal to the distance apart of the biplane wings, the structure to take bending and torsion was very much heavier. Heavier structure meant larger wings with still more weight, since the lift per unit area that the monoplane wing would give was very little higher than the biplane.

Torsion in both monoplane and biplane was taken in differential bending of the spars, the front spar taking most of the shear when the centre of pressure was forward, the rear spar taking a larger share as the centre of pressure moved back. In the terminal velocity dive, when there was practically no lift on the wing, but just a large torsion, the front spar was bent down and the rear spar bent up.

The angular twist produced on the wing due to the unequal deflection of the two spars was found to be serious, since it led to wing flutter and loss of lateral control, and increased stiffness was only obtained at the price of considerable increase in spar weight.

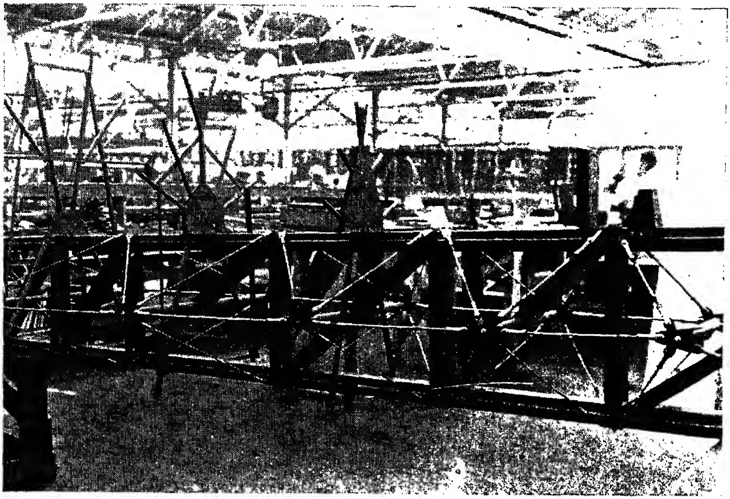


Fig. 2.—FUSELAGE SPAR. PYRAMID BRACING PROVIDES TORSIONAL RIGIDITY AND HORIZONTAL SIDE WIRES TAKE LATERAL LOADS.

The Monospar Principle

The monospar system was a solution to the problem in that a single spar was made capable of transmitting shear, bending and torsion loads. The weight of the second spar was saved. Since this was about 40 per cent. of the total spar weight the gain was considerable. Among other things, less wing weight means less wing inertia and therefore greater rolling manœuvrability. The saving in weight can be utilised commercially in carrying more pay load or in increasing the range of the aeroplane by carrying more fuel. A table is included comparing the weights and pay load of aeroplanes with normal two-spar and with monospar construction.

Comparison of Monospar with Two-spar Construction

All-up Weight.	Wing Weight—lbs.		Pay Load—lbs.	
	Two-spar.	Monospar.	Two-spar.	Monospar
2,000	403	227	440	616
4,000	805	454	880	1,231
6,000	1,210	682	1,320	1,848
8,000	1,614	910	1,760	2,464
10,000	2,015	1,136	2,200	3,079

[The assumptions made in compiling the above table are as follows :—

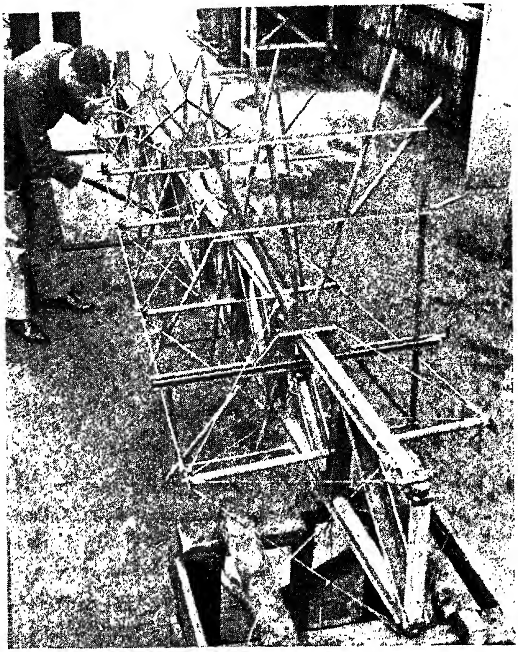


Fig. 3.—FUSELAGE SPAR, WITH STAY TUBES FOR FABRIC STRINGER SUPPORT.

The aeroplanes all have a landing speed without flaps of fifty-five miles per hour.

The pay load of the two-spar type is taken as 22 per cent. The two-spar aeroplane has a wing weight of 2·2 lbs. per square foot, the monospar wing weight being 1·24 lbs. per square foot. It will be seen that one extra passenger can be carried for an all-up weight of 2,000 lbs. and five extra passengers or a proportionate amount of extra fuel for an all-up weight of 10,000 lbs.]

The single spar is positioned at the thickest part of the wing section, giving the greatest effective beam depth. This usually occurs at about 30 per cent. of the chord and is therefore approximately coincident with the centre of pressure in its most forward position. The torsion is, therefore, least when the bending is greatest, and as the centre of pressure moves back and the torsion increases, the bending load to be taken becomes less, since lower load factors are used for design with the centre of pressure back than with it forward.

Sufficient depth for the rear spar is now not a factor to be reckoned with in selecting a suitable wing section and a thin trailing edge section such as the Joukowski series with small centre of pressure travel can be used. The wing platform can be made more closely elliptic to give the best lift distribution and least induced drag. Practical advantages include the space behind the single spar for undercarriage retraction and the ease of folding the wing by hingeing back about a continuous spar.

The centre of gravity of the monospar wing is farther forward than

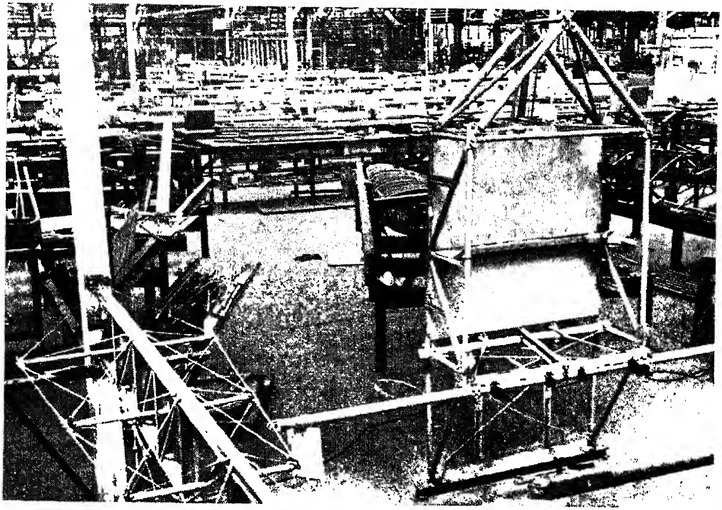


Fig. 4.—CABIN STRUCTURE TRAY STANDING VERTICALLY FOR FINAL ASSEMBLY.

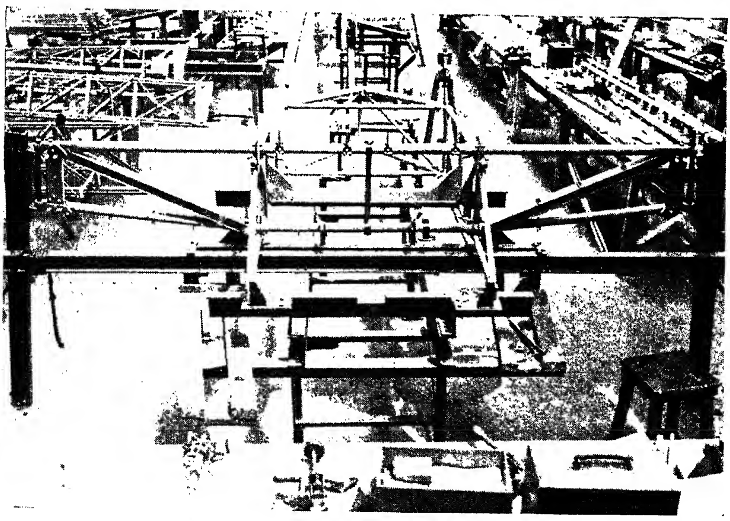


Fig. 5.—CABIN STRUCTURE TRAY ON JIG WITH CENTRE SECTION WING SPAR IN POSITION.

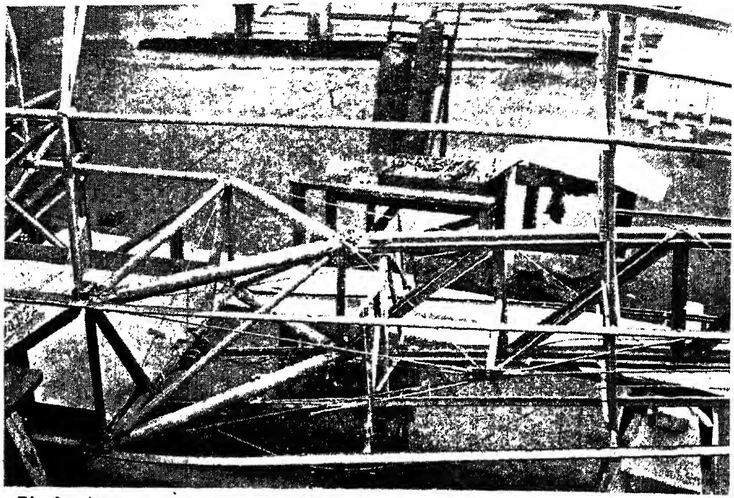
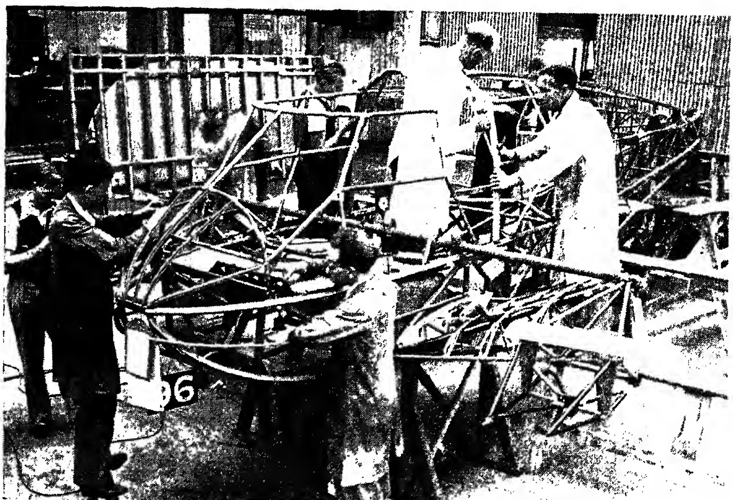


Fig. 6.—ATTACHMENT OF FUSELAGE SPAR TO CABIN TUBULAR STRUCTURE SHOWING PYRAMID WIRES AND MAIN FABRIC STRINGERS.



7.— ASSEMBLY OF CABIN SUPERSTRUCTURE. PRIMARY STRUCTURE CAN BE SEEN WITH ENGINE MOUNTINGS AND PETROL TANK IN POSITION.

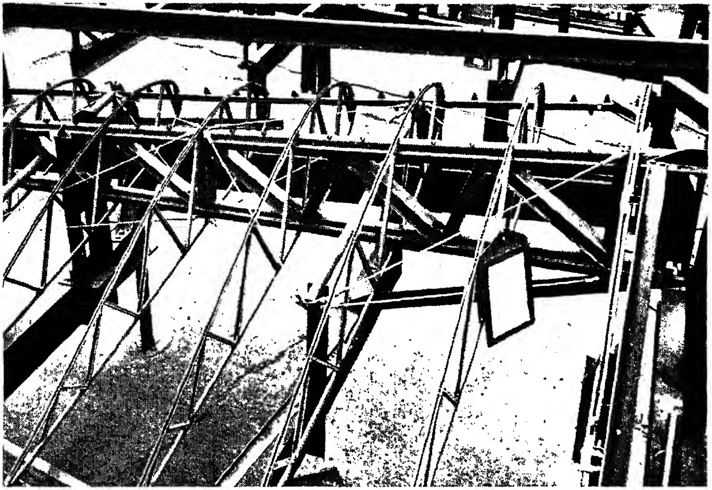


Fig. 8.—OUTER WING SPAR, WITH PYRAMID BRACING AND RIBS, ASSEMBLED ON WING JIG.

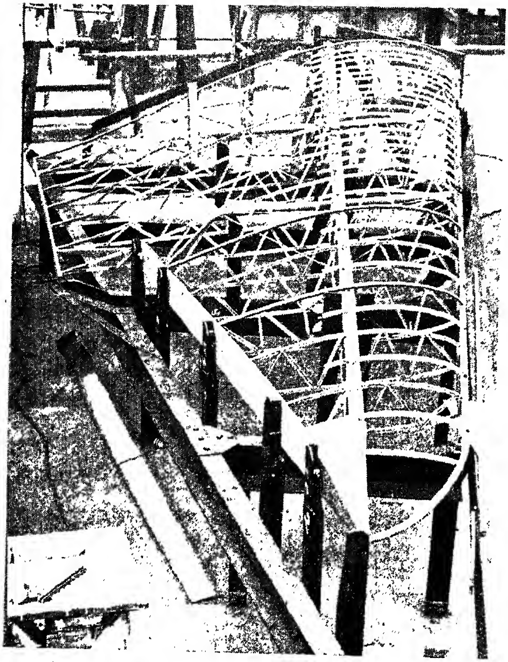
with any other type of construction. Flexural and torsional axes are coincident and the critical speed at which flutter occurs is therefore far higher than with normal two-spar construction.

The principle of monospar construction is to transmit the applied load through the shortest possible path, thus making the structure as simple and straightforward as possible. Only one path is provided for the load and the resulting lack of redundancy must therefore lead to a direct reduction in structure weight.

Wing Construction

The spar is built up as an "N" girder taking shear and bending. Pyramids of high tensile steel rods are built on to the front and rear faces of the spar with the spar as a base. The effect is that of winding two tension helices round the spar in opposite directions, crossing on the upper and lower booms and also at the extreme points which they reach forward and aft of the spar centre line. The front apices of the pyramids are arranged to coincide with the wing leading edge, to which they are attached and a compression strut holds the front and rear apices apart. A member in the leading edge running along the wing picks up the front apex of each pyramid to provide a path for drag loads.

The stresses and deflections in this structure can be accurately calculated. Vertical shear and bending must go through the spar since



9.—OUTER WING BEFORE COVERING. THE AILERON IS MOUNTED AFTERWARDS.

there is no other path. Torsion will travel through the tension helices, and drag through the horizontal beam made up of spar and leading edge members with the front pyramids acting as drag bracing wires.

The accurate calculation of torsion stresses is particularly important, since the torsional deflection of the wing can thereby be found. Any required torsional rigidity can be given to the wing simply by regulating the size of the pyramid wires.

The wires are given an initial tension of approximately one-third of their breaking load. The ultimate torsion taken by the system is just the same as if there were no initial tension, one-third of the load passing in compression into the appropriate wire and making it go slack when two-thirds the ultimate torsion has been applied. At this point the tensioned wire has only one-third its breaking load, or one-half the load it would already have taken without initial tension. Since two-thirds the ultimate torsion is the most that will be experienced by the aeroplane operating under normal conditions, the effect is that initial tension halves the free deflection of the monospar wing.

A wing was made up for a Fokker FVII using this principle. It was found that the pyramid bracing bays would be increased in the ratio 3·42 : 1 in stiffness for a wing weight increase from 1·24 lbs./sq. ft. to 1·35 lbs./sq. ft. This confirmed the high efficiency of the pyramid bracing as a torsion-resisting medium compared with the weight involved.

The pyramid bases are arranged to give stiffly supported points on the

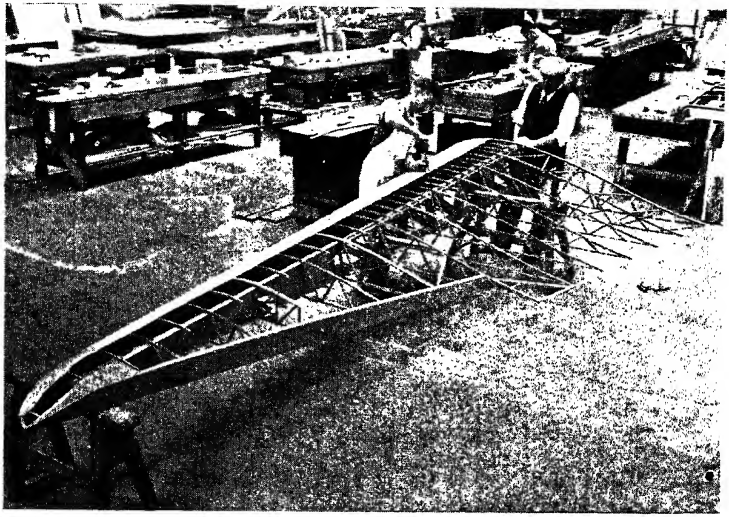


Fig. 10.—ATTACHING PLYWOOD COVERING TO THE LEADING EDGE.

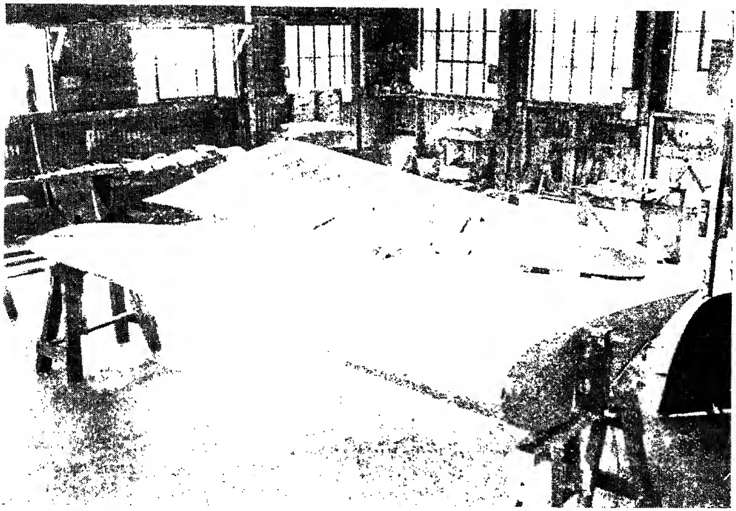


Fig. 11.—MONOSPAR WINGS IN THE DOPE SHOP.

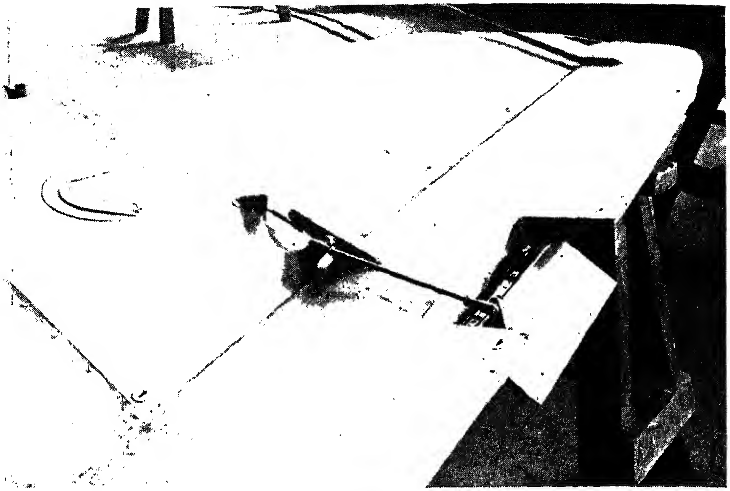


Fig. 12.—VIEW OF UNDERSIDE OF AILERON SHOWING TRIMMING FLAP AND MASS BALANCE.

spar for the attachment of undercarriage structure and wing nacelles. This is a further saving of weight over two-spar construction where heavy torsion ribs must be provided.

The various points of attachment of the wires to the spar stabilise the spar compression boom at frequent intervals. This enables the boom material to develop a high stress and to be made for the minimum of weight.

After the aeroplane has been finished, rigging alterations can easily be carried out by adjustment of the pyramid bracing.

Ribs are attached to the spar and leading edge members. Since most of the pressure on the wing comes on the forward 30 per cent. of the chord, between the two attachment points, the ribs are as light as with two-spar construction.

Towards the wing tip where the wing thickness is small, a torsion rib is thrown back on to the aileron auxiliary spar providing local stiffness where the torsion loads are too small to warrant the provision of a pyramid.

Fuselage Loads

During flight stabilising loads are applied by means of the elevator and rudder to control the attitude of the aeroplane. A large down load is exerted by the air on the tailplane and elevator when the aeroplane is in a fast dive. The fin and rudder have to withstand a large side load

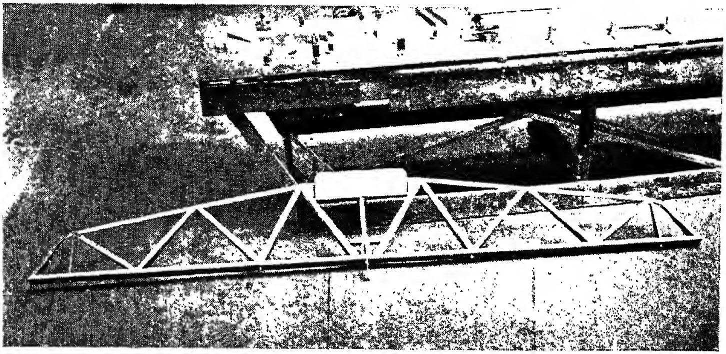


Fig. 13.—ELEVATOR STRUCTURE. NOTE THE TORSION RIBS AND TRIMMING FLAP.

when the rudder is applied suddenly or, with multi-engined types, when an engine stops and the rudder is used to prevent excessive yaw. On landing, the ground reaction on the tail wheel has to be carried forward through the fuselage structure until it is all balanced out by gravity forces.

Fuselage Construction

The space in the rear fuselage is of little practical use since centre of gravity limitations prevent the stowage of heavy articles far behind the wing. The " four longeron " construction is inefficient from the weight standpoint, because of the waste of effective height within the section, whose best aerodynamic shape is something between a circle and an oval. Monospar construction can be designed to have its cruciform beam coincident with the major and minor axes of the fuselage section, thus utilising the greatest effective spar depth and saving weight.

The fuselage spar is made up in the same way as the wing spar except that the spar lies along the fore and aft centre line of the aeroplane with pyramids on either side and the apices are joined on each side by wires. The shear on the tailplane and elevator is taken by the spar. Since the shear is due to practically symmetrical loading on the tail on both sides of the centre line, the torsion is small and the torsion wires are not stressed.

When the rudder is loaded the resultant shear is usually applied well above the centre line of the fuselage. This is because in the conventional layout the greater part of the fin and rudder surface is above the fuselage. The rudder shear having a leverage about the fuselage, a torsion is associated with the sideways bending, and the monospar system is admirably suited to deal with this.

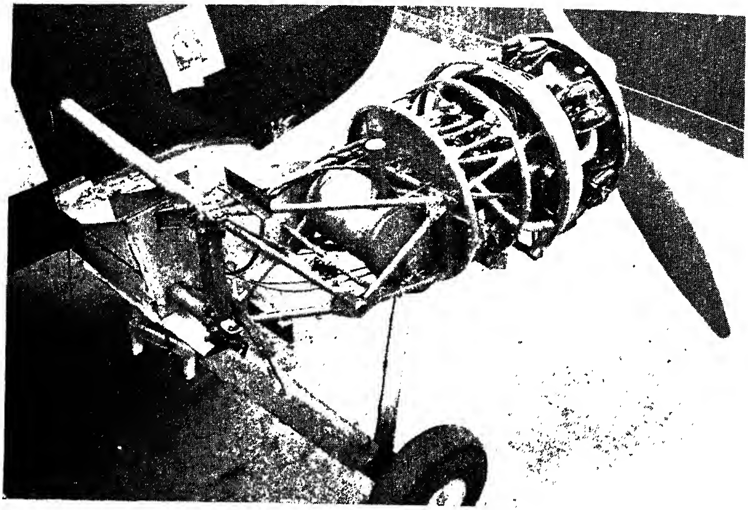
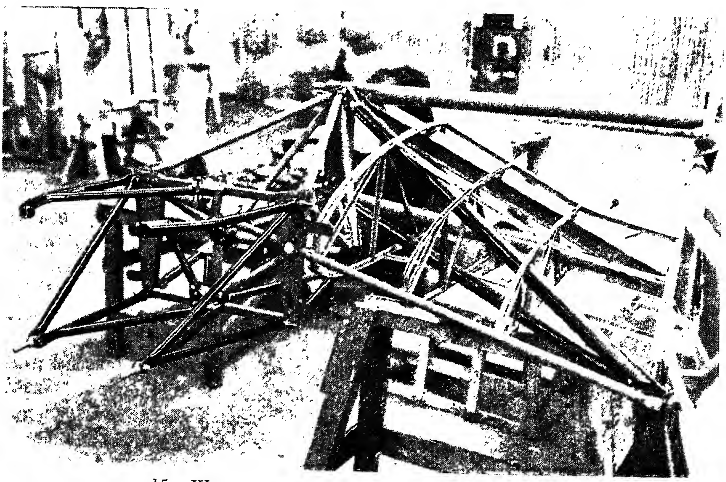


Fig. 14.—POWER PLANT ASSEMBLY, SHOWING OIL TANK IN POSITION.



15.—WING STUB WITH ENGINE MOUNTING STRUCTURE.

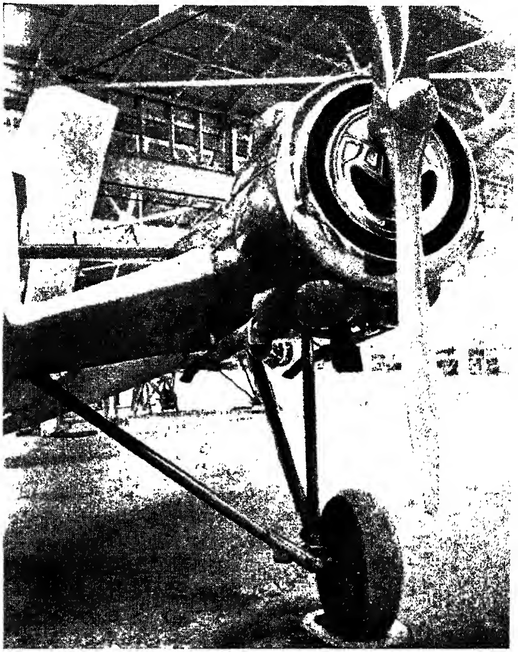


Fig. 16.—WING NACELLE AND UNDERCARRIAGE ASSEMBLY.

By the time the loads have been transmitted as far forward as the spar they are neutralised to a great extent by balancing forces. The shear due to ground reaction is greatly reduced by gravity loads in the fuselage and tail unit stabilising loads are passed into the wing. It is then possible to build a tray consisting of two sides and a floor to look after the remaining loads and to provide the primary structure necessary to house seats and cabin equipment. The change-over from monospar to tray construction is effected through a torsion bulkhead normal to the fore and aft line.

Description of the Monospar "Universal"

General Aircraft Limited have developed a twin-engined low-wing cantilever monoplane designed to carry a pilot and four passengers. The monospar principle is used throughout and the accompanying photographs show details of the manufacture and assembly.

The primary structure is all metal adequately protected against corrosion.

Outer Wings

The outer wing panels are of cantilever design and taper considerably towards the tip. Each is attached to the centre section by two main hinge fittings on the spar, about which it can swing back for folding.

Wing folding is simple and rapid and can be done by one man. The centre plane flap is hinged up sideways against the fuselage, the leading edge catch is opened and the outer wing then folds back.

The spar booms are of built-up duralumin sheet riveted into a closed section which develops a high compressive stress before failure. Flanged dural web plates are bolted on to the sides of the spar booms and the pyramid wires are attached by means of mild steel wiring lugs to the top and bottom of the complete spar. At the pyramid apices the wire shackles meet on star-shaped steel plate fittings.

The compression struts, which hold the front and rear pyramids apart, are made of cold drawn steel tube. Their free strut length is halved by lateral stabilising where the tubes pass the web diagonals; they are therefore not of such heavy gauge as if they acted as struts over their full length, when the Euler failing load would be much smaller.

The leading edge drag member is a dural channel section.

Out towards the wing tip where the shear and torsion loads are small the web "N" bracing is replaced by a duralumin sheet which is attached to the top and bottom spar booms. The pyramids are discontinued and the aileron auxiliary spar is linked up to the main spar to provide a torsionally rigid structure.

The ribs are made of extruded dural section and pick up on the main spar and leading edge member through dural angle brackets. Over the leading edge the rib spacing is halved to ensure a close approach to the required wing section under the air pressure. When the ribs are in position a layer of plywood is placed round the nose and the wing is then covered with fabric.

Ailerons

The ailerons are of fabric-covered metal construction, the spar and ribs being made of duralumin sheet. An open channel section is used for the aileron spar to give ease of rib assembly. The ribs are riveted diagonally on to the spar channel and lap into each other at the trailing edge. This arrangement gives a stiff framework and provides a valuable safeguard against flutter. The ailerons are mass balanced by lead weights carried forward of the hinge line below the wing.

Centre Structure

The centre plane tapers in thickness towards the wing root at the side of the cabin, leaving a well-faired wing spar top boom in free air. This arrangement improves the airflow over the wing root where excessive turbulence might adversely affect the tail control and give corresponding lack of stability.

The centre section is integral with the fuselage, the wing spar passing right through the cabin. Three point attachment is provided, torque and drag struts of steel tube picking up on the forward cabin structure.

The engine mounting and undercarriage members are attached to this centre section, their detail arrangement being clearly brought out in the photographs.

Undercarriage

The undercarriage consists of two independent legs with a wide track. It is made up of three members, an axle leading to the fuselage, a radius rod, and a shock absorber leg containing three coil springs and a friction damping device.

The wheels are fitted with low-pressure tyres and hydraulic brakes, with differential control, connected to the rudder bar.

The tail wheel, which is sprung and fully castoring, is also fitted with a low-pressure tyre.

Fuselage

The fuselage structure is designed along the lines mentioned earlier in this article. The front end is a shallow tray of tubular construction which takes the cabin equipment. The rear end is built on the monospar principle in the same way as the wings. A duralumin spar leads right back to the sternpost and is stabilised by two tension helices with side wires of high tensile steel rods.

The upper part of the body is entirely built up of light dural secondary structure which carries little load and serves only to take fabric covering. Formers radiate from light angles which are mounted on the fuselage spar top boom. Stringers of extruded section running fore and aft along the fuselage are riveted on to the extremities of the formers, the framework is then covered over with fabric. In the front fuselage the stringers are mounted on hoops. The absence of highly stressed members in the upper part of the body makes it very easy to provide breaks in the structure for doors. Advantage has been taken of this to instal a large loading hatch in the side as well as a hinged roof and side entrance door.

Tail Unit

The tailplane is built as a two-spar semi-cantilever structure supporting a fin and rudder at each end. Tailplane and elevator spars are of dural channel, the elevator torsion being transmitted along the spar by diagonal ribs linked together at their trailing edges.

The twin rudders are mass balanced by the rudder control rod, which is carried inside the tailplane. A trimming tab is provided on the elevator.

A PICTORIAL SURVEY OF TYPICAL PRODUCTION OPERATIONS

DEALING WITH LATHE WORK, PANEL BEATING, JIG BORING AND THE USE OF BENDING BLOCKS IN CONJUNCTION WITH A HAND PRESS

IN foregoing articles in this work reference has been made to various workshop processes in connection with the production of aeroplane components.

Through the courtesy of Messrs. Handley Page, Ltd., we have been able to obtain a series of pictures illustrating some of the most important routine workshop processes used in the construction of all-metal aeroplanes, and these pictures are reproduced in the following pages.

The photographs have been divided into five groups.

Machining Operations

The first group (Figs. 1–8) illustrate the sequence of machining operations on a forged heavy metal fitment. These are followed by a series (Figs. 9–13) illustrating the production sequence for producing small turned components on a light capstan lathe.

Panel Beating

In the third series (Figs. 14–22) is shown the process of panel beating and the building up of an engine nacelle. The process of panel beating is extremely interesting. After the sheet has been cut to the approximate shape it is beaten on a sand cushion with a wooden mallet. It is then smoothed out and brought nearer to final shape by "planishing" with a highly polished steel hammer. This process removes dents and wrinkles caused by the "bossing" operation.

Following the "planishing" operation the panel is run to and fro between rollers which may be adjusted to give the required pressure. This removes all hammer marks and brings the metal to a uniform thickness.

Jig Boring

The remaining pictures deal with jig boring (Figs. 23–24) and the use of bending blocks in conjunction with a hand press (Figs. 25–29) such as is frequently used for shaping the small metal components used in aeroplane construction.

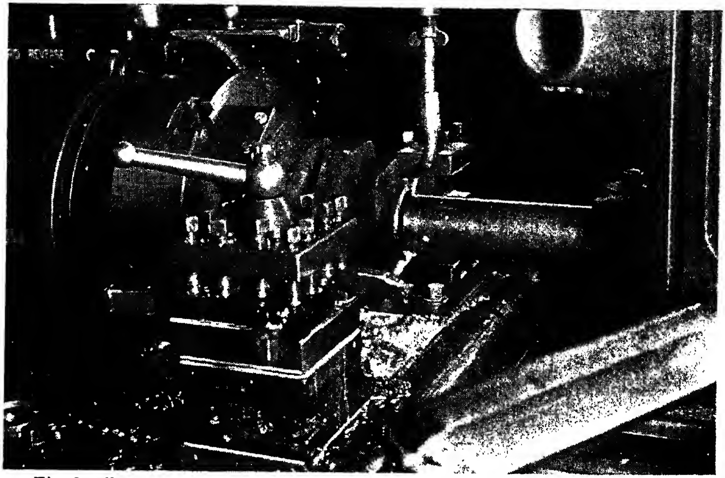


Fig. 1.—PRODUCTION OF LARGE MACHINED FITTING ON NO. 8 WARD LATHE (1). Showing rough forging set up in machine for boring operation.

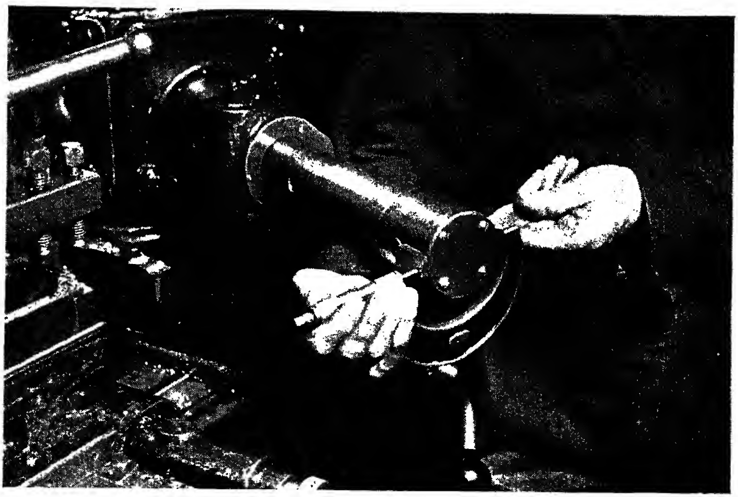


Fig. 2.—PRODUCTION OF LARGE MACHINED FITTING ON NO. 8 WARD LATHE (2). Setting cutting edges of boring tool to give required bore diameter, using micrometer.

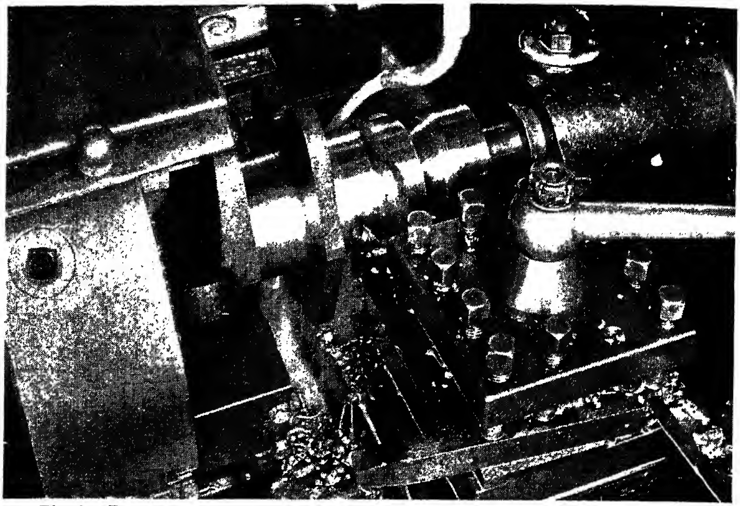


Fig. 3.—PRODUCTION OF LARGE MACHINED FITTING ON NO. 8 WARD LATHE (3).

After boring, the forging is rough-machined all over, and is here seen undergoing the final or "finishing" cut which brings the barrel to the required degree of accuracy and smoothness.

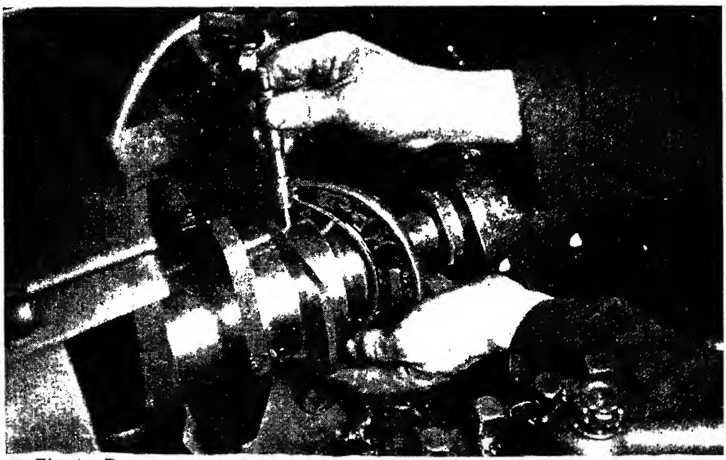


Fig. 4.—PRODUCTION OF LARGE MACHINED FITTING ON NO. 8 WARD LATHE (4).

Testing with micrometer for accuracy of diameter of barrel.

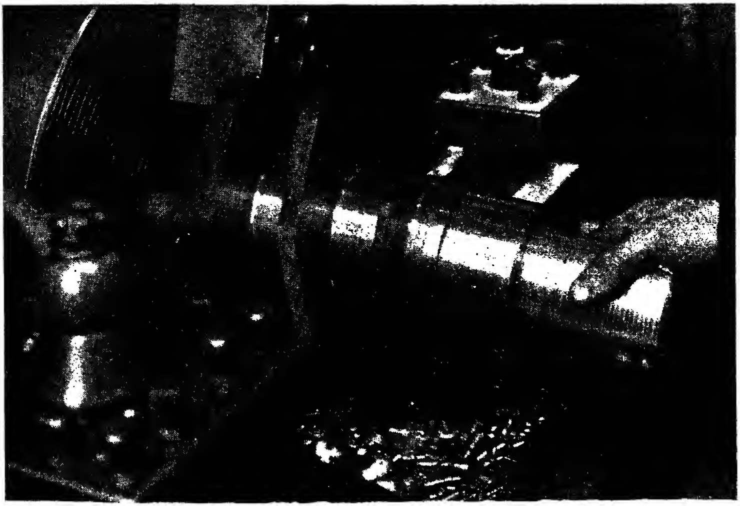


Fig. 5.—Production of large machined fitting on No. 8 Ward lathe (5). Testing for accuracy of bore with plug-gauge.

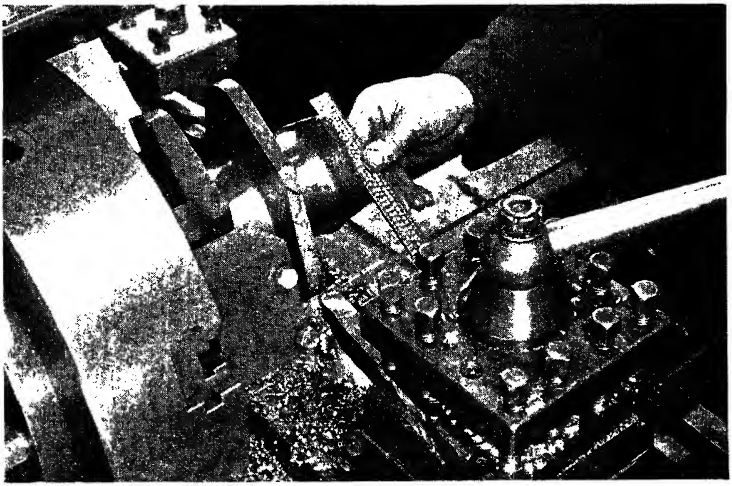


Fig. 6.—Production of large machined fitting on No. 8 Ward lathe (6). Setting lathe tool for finishing cut on webs of fitting, to bring gap to required dimension.

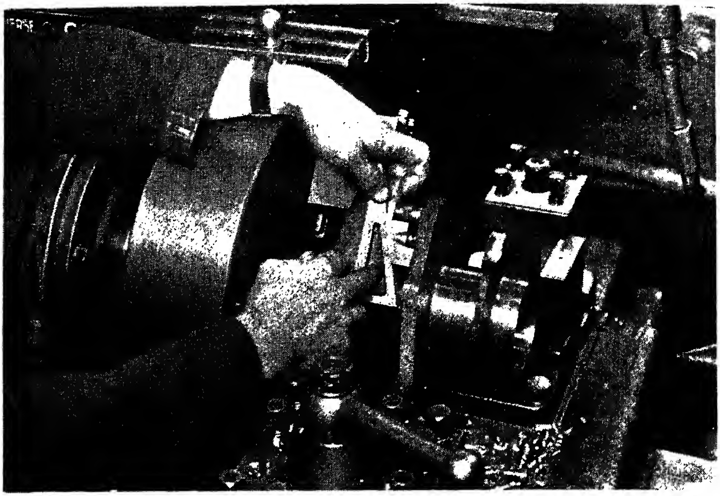


Fig. 7.—PRODUCTION OF LARGE MACHINED FITTING ON NO. 8 WARD LATHE (7). Testing gap between webs with an adjustable gauge block.

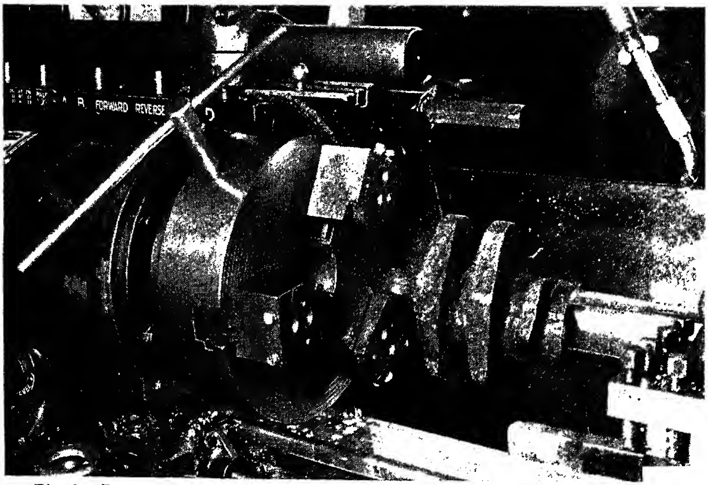


Fig. 8.—PRODUCTION OF LARGE MACHINED FITTING ON NO. 8 WARD LATHE (8). Photograph showing jaws of chuck shaped to fit forging.

Fig. 9.—PRODUCTION OF SMALL TURNED COMPONENT ON A LIGHT CAPSTAN LATHE (1).

Jaws of chuck opened to allow bar to slide up against stop. This is arranged to leave a predetermined amount of material projecting. The "capstan" rotates automatically as each tool is withdrawn from the work, bringing a fresh tool into line ready for the next operation.

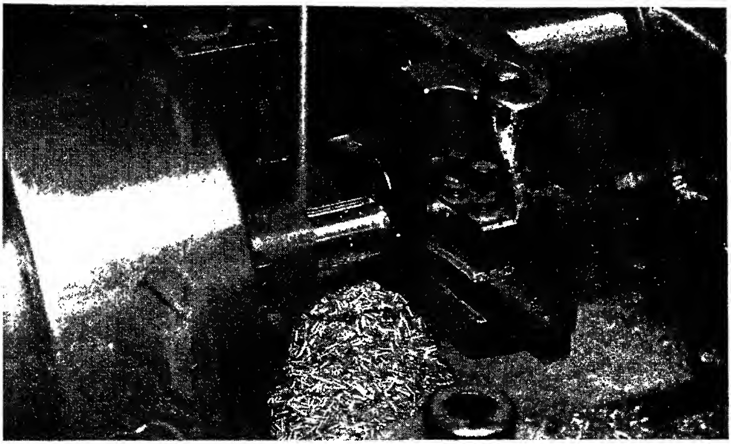


Fig. 10.—PRODUCTION OF SMALL TURNED COMPONENT ON A LIGHT CAPSTAN LATHE (2).

Here the bar is turned down to the required diameter. Note the rollers to steady the work and maintain uniform accuracy.

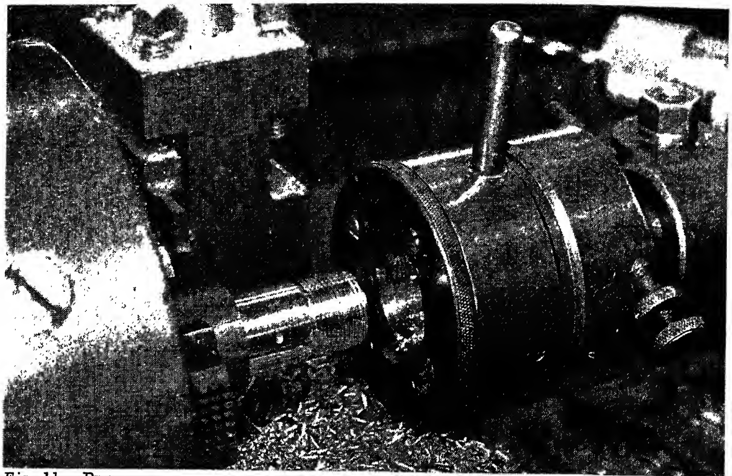
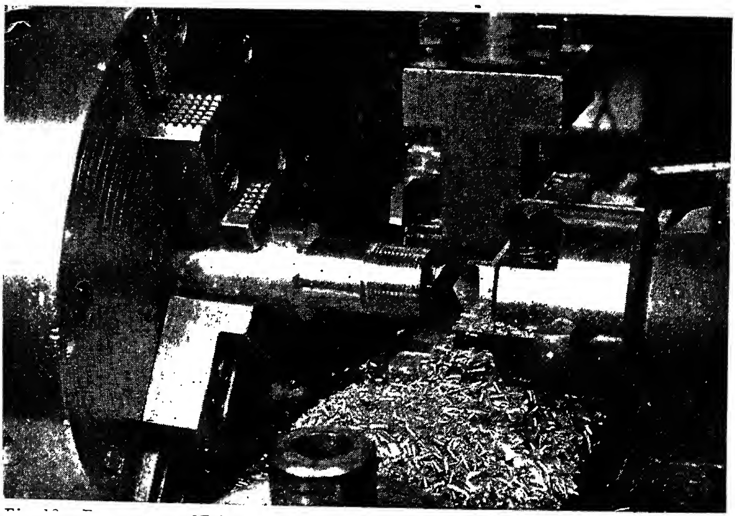


Fig. 11.—PRODUCTION OF SMALL TURNED COMPONENT ON A LIGHT CAPSTAN LATHE (3). Thread cut with Herbert die-box. Showing the box being withdrawn after the thread-cutting operation.



OF SMALL TURNED COMPONENT ON A LIGHT CAPSTAN LATHE (4) Centring the end of bar to ensure concentricity in the subsequent drilling operation.

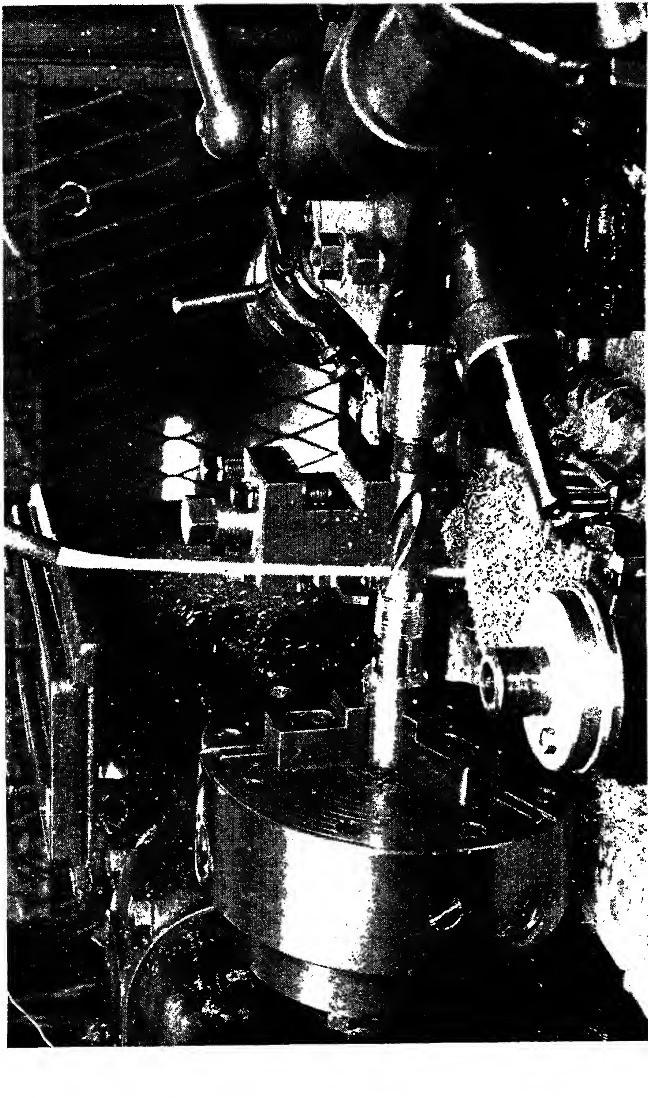


Fig. 13.—PRODUCTION OF SMALL TURNED COMPONENT ON A LIGHT CAPSTAN LATHE (5).

Showing the drilling operation. The depth of the hole is governed by suitably adjusted stops, as in the case of operations shown in Figs. 9, 10 and 11. The work is then parted off with the tool mounted (inverted) in the tool post, and the cycle of operations is ready to start again.

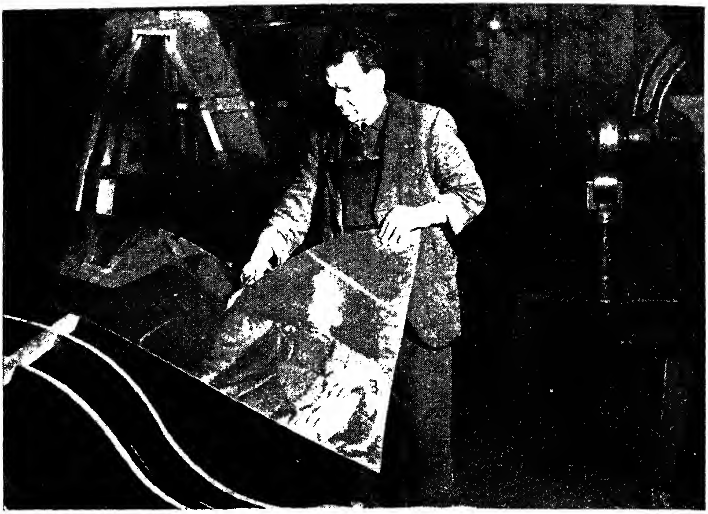


Fig. 14.—PANEL BEATING (1).
Cutting out the sheet to approximate shape.

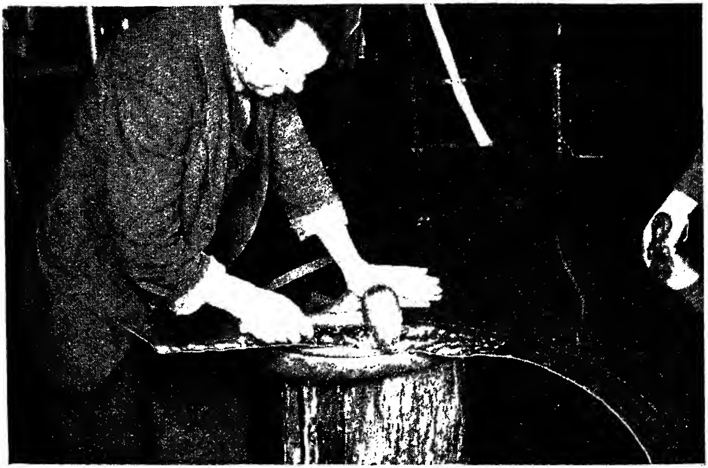


Fig. 15.—PANEL BEATING (2).
Beating the panel to shape on a sand cushion.

Fig. 16.—PANEL BEATING (3).

After the panel has been beaten roughly to shape on a sand cushion with a wooden mallet, it is smoothed out and brought nearer to final shape by "planishing" with a highly polished steel hammer. This removes dents and wrinkles caused by the "bossing" operation.

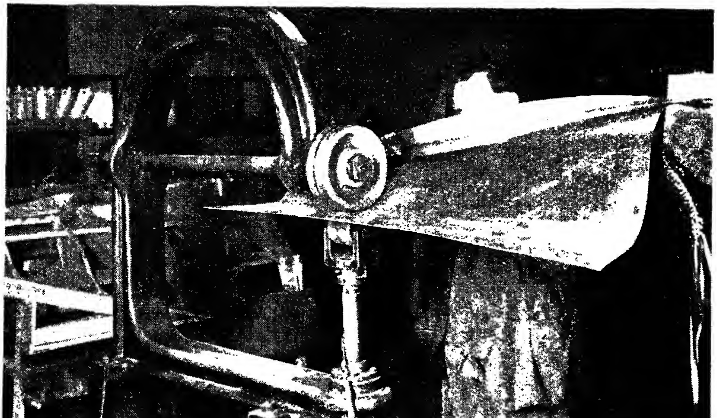


Fig. 17.—PANEL BEATING (4).

After being "planished," the panel is run to and fro between rollers which may be adjusted to give the required pressure. This removes all hammer marks and brings the metal to a uniform thickness.

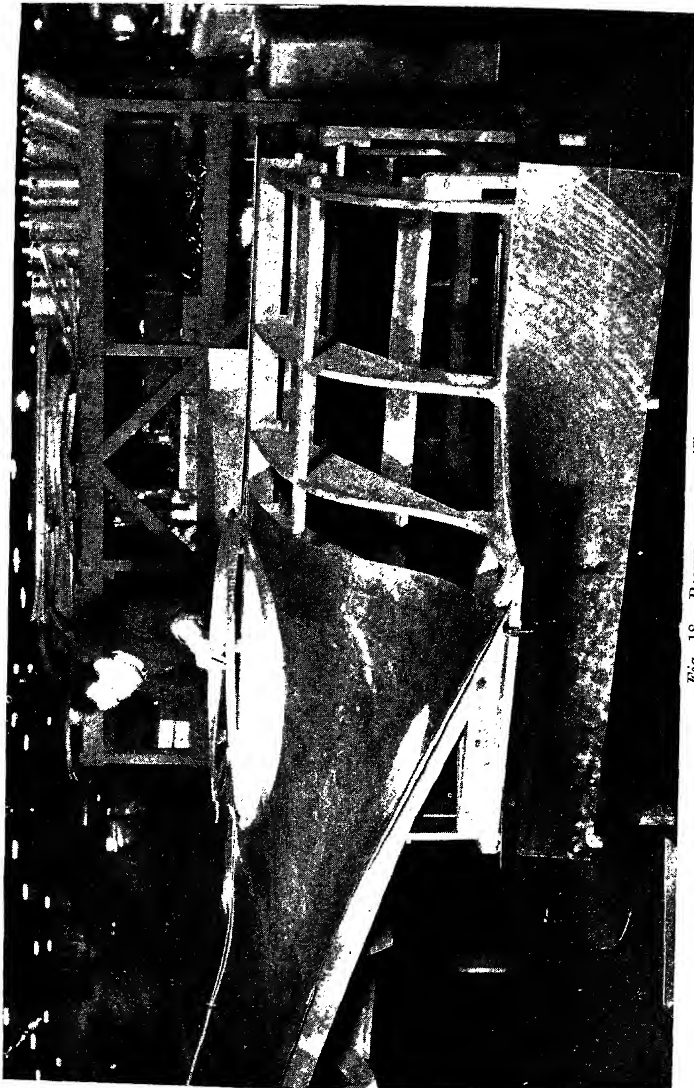


Fig. 18.—PANEL BEATING (5).

Finally, the shape of the panel is adjusted to fit exactly on a wood jig made for this purpose.

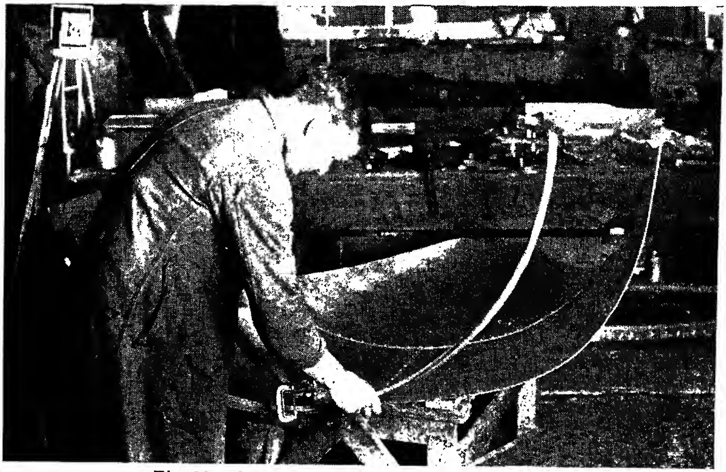


Fig. 19.—COMPLETION OF BEATEN PANELS (6).
Clamping stiffening members on panel.

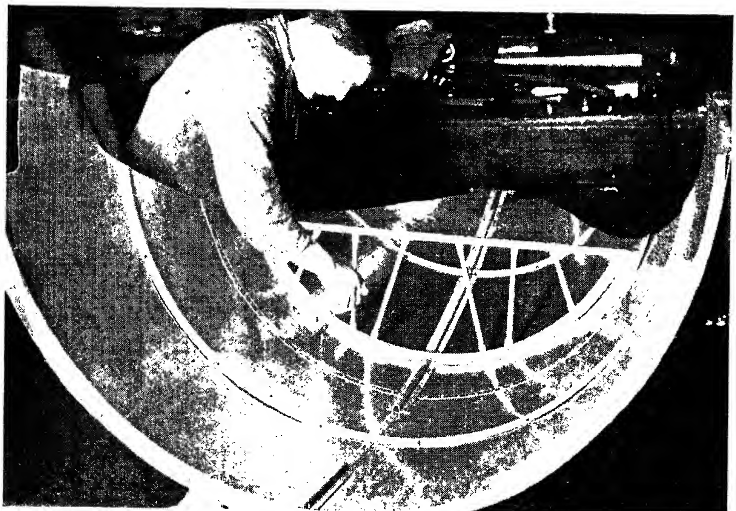


Fig. 20.—COMPLETION OF BEATEN PANELS (7).
" Service-bolting " members to panel with small nuts and bolts, to facilitate drilling.

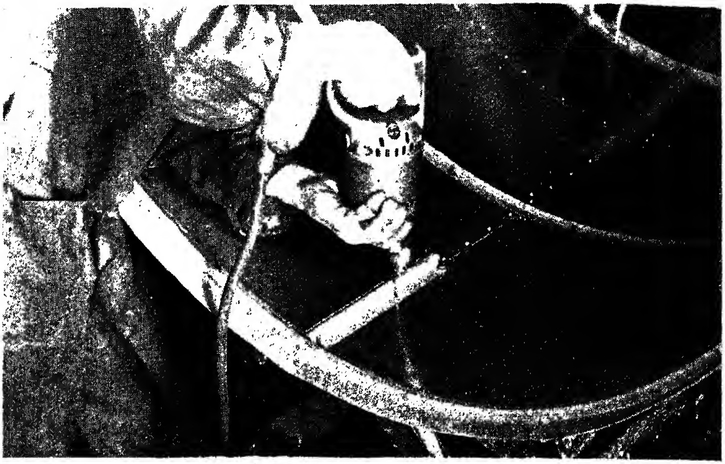


Fig. 21.—COMPLETION OF BEATEN PANELS (8).
Drilling rivet-holes with stiffener temporarily bolted in position.

Fig. 22.—COMPLETION OF BEATEN PANELS (9).
Riveting stiffening members in place. Finally, service bolts are removed, holes drilled out and rivets inserted.

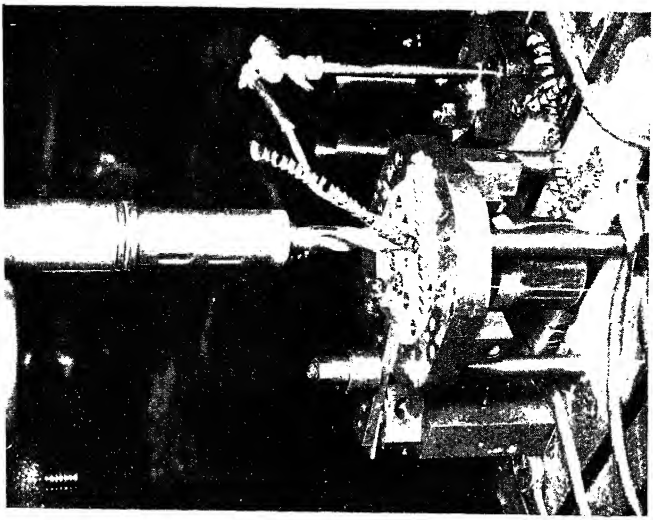


Fig. 23.—JIG-BORING (1).
Showing a simple boring-jig in use.

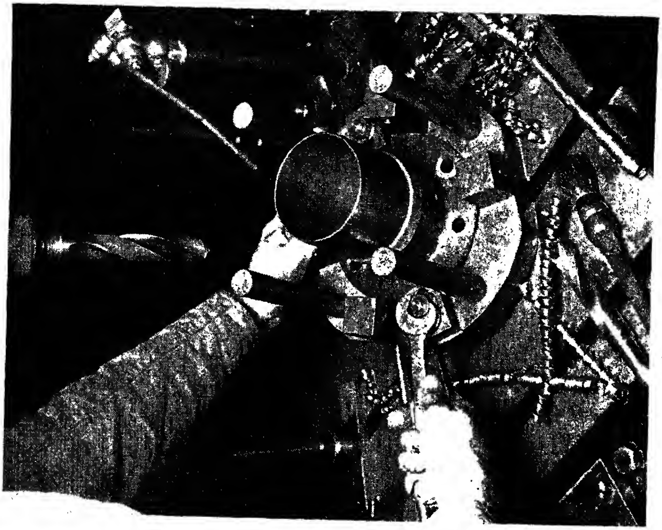


Fig. 24.—JIG-BORING (2).
View of underside of jig, illustrating simple method of holding work.

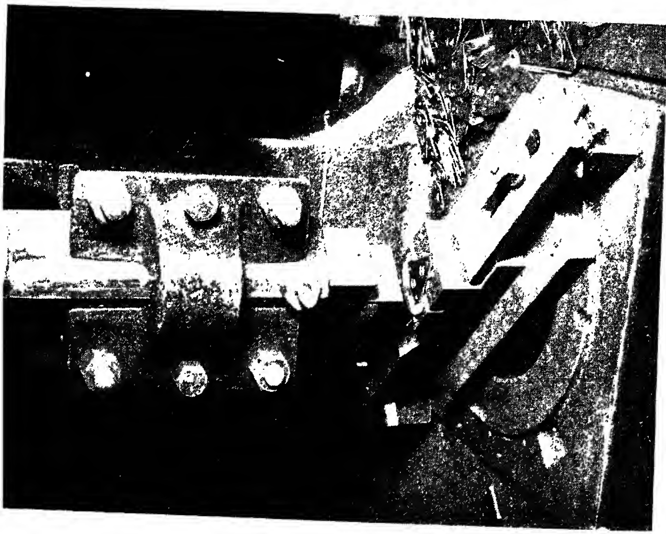


Fig. 25.—BENDING OPERATION ON HAND-PRESS (1).
Showing the press set up ready for bending a small steel fitting. Note the method of holding the work in the correct position.

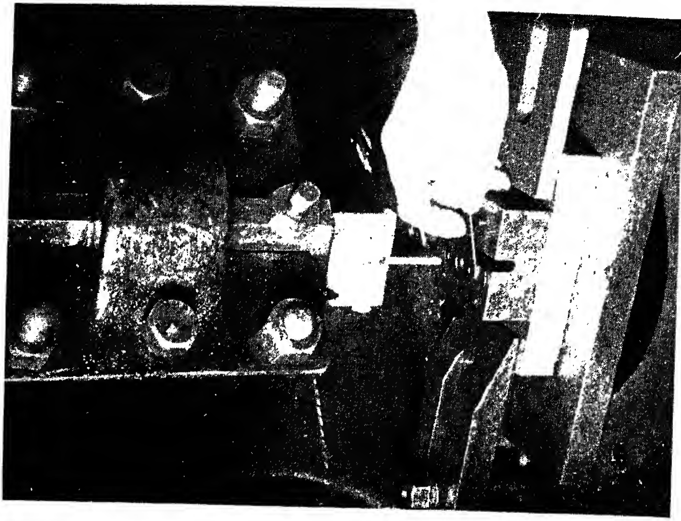


Fig. 26.—BENDING OPERATION ON HAND-PRESS (2).
The operator places the blank in position.

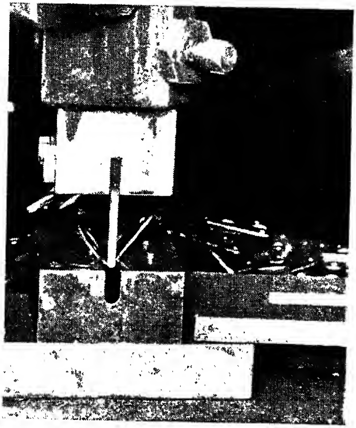


Fig. 27.—BENDING OPERATION ON HAND PRESS (3).
The bending operation in progress.

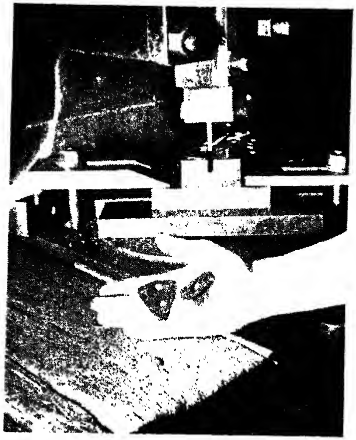
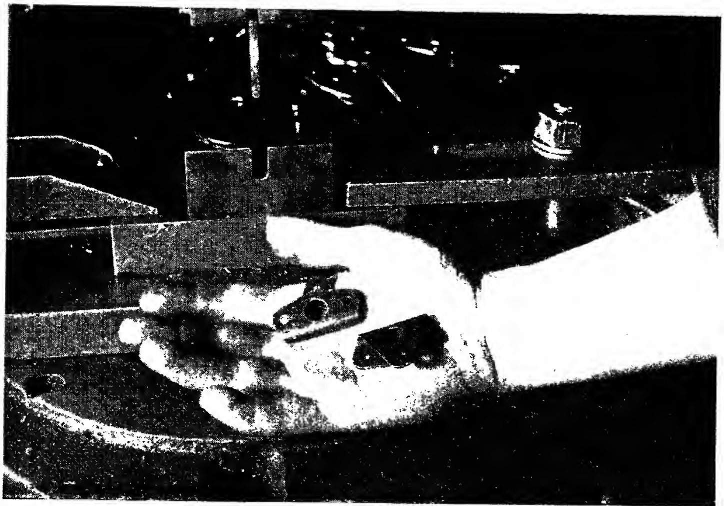


Fig. 28.—BENDING OPERATION ON HAND-PRESS (4).
The blank before and after bending.



g. 29.—BENDING OPERATION ON HAND-PRESS (5).
The completed fitting.

INSTALLATION OF CABLES AND PREPARATION OF TERMINAL ENDS

By C. C. Jackson, *De Havilland Aircraft Co.*

THE majority of failures of the electrical installations in service can be traced to broken wires at the terminal ends. During installation every care should be devoted to the prevention of these breakages by ensuring that the cable ends are correctly prepared, that the strands of the conductors are not cut or nicked and that each cable is securely anchored at a point 2 to 3 in. from the terminal, with a loop between the fixing and the component to absorb vibration. The completely screened aeroplane is less liable to suffer from cable fractures in service because the external metal braid is clamped to the component by a gland and the cable will stand up to rougher treatment than it is likely to receive on the aeroplane (Fig. 1).

Where cables are carried in ducts they are supported throughout their length and are protected from accidental damage, but care must be taken during installation not to subject the cables to undue strain and to ensure that all ducts and fairings and screening boxes are free from any sharp edge or roughness.

Cables should be mounted as far as possible from the compass to avoid interference from the magnetic field and where possible cables should be paired, negative and positive, so that the inductive effects of the one are neutralised by the other.

Preparation of Cable Ends (Figs. 2A and 2B)

(*a*) Ross Courtney claw type end. The cable is stripped back to a length equal to the mean circumference of the inner washer and a loop formed as shown in Fig. 2A. The loop is fitted to the cup half, the washer placed on the wire and the claws turned over and squeezed tight.

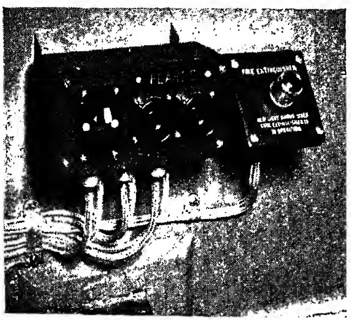


Fig. 1.—Example of screened cables.

(*b*) The Ross Courtney soldering tag. The wire is stripped back enough to hold with a pair of pliers and the rubber turned back. The tag is slipped over the wire and the stripped portion cut off. The wire is spot soldered at x and the rubber turned back over the

terminal shank. For thin wires, additional security can be obtained by the use of a rubber sleeve 1 in. long slipped over the end of the wire and terminal shank.

(*c*) Air Ministry type terminal on terminal blocks, voltage regulators, etc., consisting of a circular hole with a diametrical slot cable entry, cheese-head screw and floating washer. The cable is stripped for a length equal to half the circumference of the washer and the cable inserted under the washer so that the free end rotates in the direction of the screw thread when tightening up.

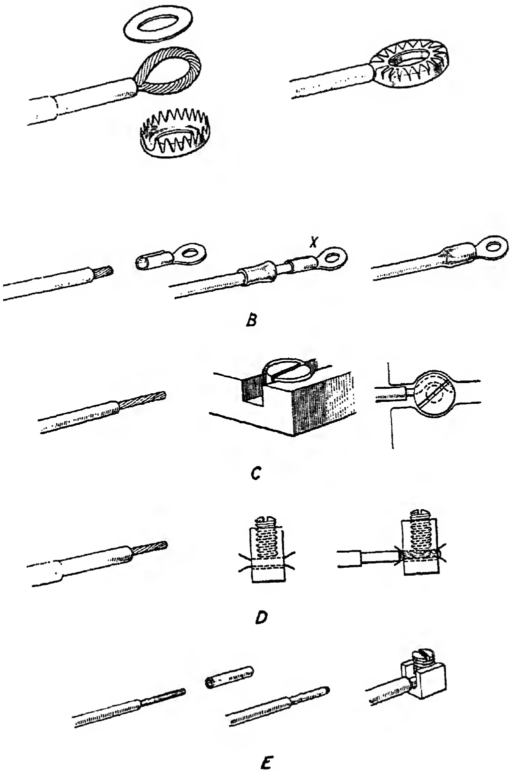


Fig. 2A.—METHODS OF PREPARING CABLE ENDS AND TERMINALS FOR CONNECTIONS TO VARIOUS TYPES OF TERMINAL POST.

A, Ross Courtney claw type end ; *B*, Ross Courtney soldering tag ; *C*, Air Ministry type ; *D*, De Havilland type terminal pillar with cable clamps ; *E*, tubular thimble.

(*d*) De Havilland type terminal pillar with cable clamps. The wire is stripped back for a distance equal to the width of the terminal post and inserted between the two shaped clamps and the grub screw tightened up.

(*e*) Tubular thimble used on magneto terminals and plain grub screw terminal posts. The cable is stripped back for a distance equal to the length of the thimble (0·5 in.) and the thimble slipped over the cable and spot soldered at the tip.

(*f*) Chater Lea terminal. The cable is stripped back for a distance equal to the length between the bottom of the socket and the hole in the

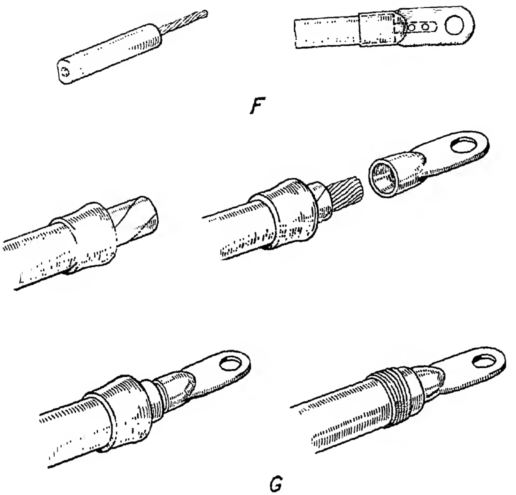


Fig. 2B.—METHODS OF PREPARING CABLE ENDS AND TERMINALS FOR CONNECTIONS TO VARIOUS TYPES OF TERMINAL POST. *F*, Chater Lea terminal; *G*, heavy duty starter cables.

flat, the cable is inserted and the flat squeezed up and spot soldered.

(*g*) Heavy duty starter cables (CTS). The outer rubber is turned back and the inner rubber is cut away for a distance equal to the depth of the socket. The cable is then sweated to the socket, the terminal being held in a vice or wood block while heat is applied until the solder flows. The joint is allowed to cool, tested for mechanical strength and the outer rubber turned over the shank and whipped with stout thread or finished with Hellerman sleeve.

Metal Braided Cable, Finishing Off the Braid

(*a*) The outer sleeve is slipped over the cable, the braiding is then stripped back with curved scissors or special hooked stripping tool and trimmed up. The inner sleeve is introduced under the braid so that the braid overlaps the sleeve by $\frac{1}{8}$ in. and the two sleeves are squeezed together with special pliers or a block and punch (Figs. 3 and 4, *A*).

(*b*) Using 22 or 24 S.W.G. tinned copper wire whipping (Fig. 4, *B*). Insert one end of binding wire under a braid and bind for the required length—$\frac{1}{4}$ to $\frac{3}{8}$ in. will suffice in most cases; then insert the end of the wire under the braid as at the start of the binding. Tin the binding with a soldering iron just hot enough to run the solder. Trim back the braid and turn the free ends of the wire over the binding and solder.

The flux used on all cables should be non-corrosive; resin or resin-cored solder is recommended for this work.

Inspection and Testing of Installations

When the circuit is complete and before connecting up batteries the

circuit should be thoroughly checked to drawing for correct type and size of cables. Check for correct finish of cable ends and terminals, slack wiring, carelessly fitted clips and chafing points likely to damage wiring and for signs of damage to wiring during assembly of aeroplane or trimming. All cable ends are correctly marked. Check fuses for correct capacity.

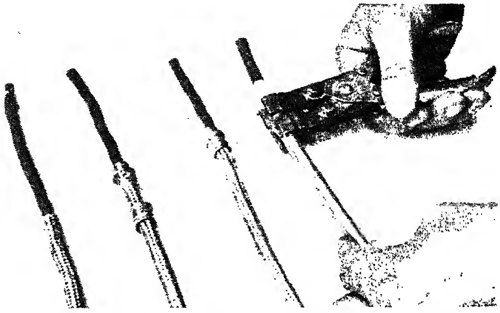


Fig. 3.—FINISHING OFF BRAIDING WITH METAL SLEEVES.

Continuity Test

Test all circuits with a lamp or buzzer and battery for correct connections. If the lamp or buzzer pass a fairly high current (2 to 3 amperes) detection of faulty contacts will be easy.

A buzzer of the H.F. type of cycle horn is perhaps the most suitable owing to its sensitivity to changes of resistance, the change being registered aurally.

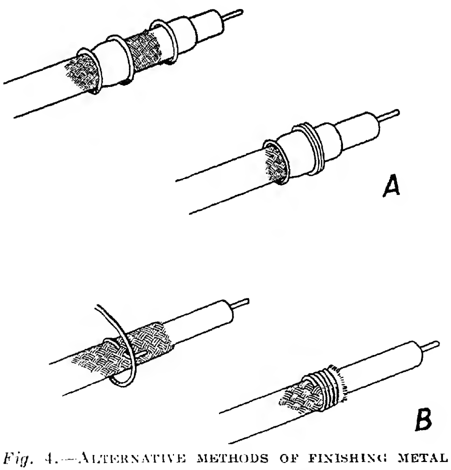


Fig. 4.—ALTERNATIVE METHODS OF FINISHING METAL BRAIDING OR SCREENED CABLES.

Method *A* is one in general use; method *B* is used where cables are of size not catered for by existing metal sleeves.

Insulation Resistance Test

This test is made using a 500-volt megger and insulation resistance is measured between poles, from positive pole to earth and from negative pole to earth. Prior to test all lamp bulbs must be removed and generator leads disconnected. Disconnect negative lead from cut-out. Close points of cut-

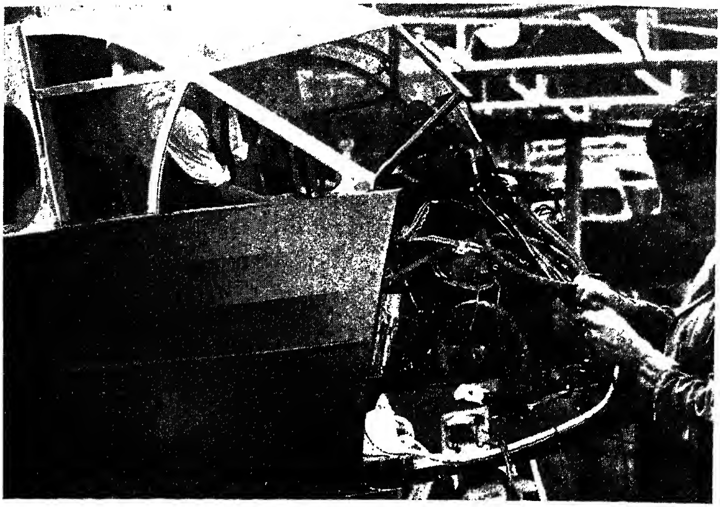


Fig. 5.—CIRCUIT TESTING.

out or short terminals A and 5 +. Close all switches. Disconnect electric fuel gauges, voltmeter and any closed circuit.

Test 1—" Between Poles "

Connect leads from megger to the battery terminals, negative and positive, and apply the test pressure by turning the megger handle at a uniform speed for one minute.

Test 2—" Positive Pole to Earth "

Connect one lead of the megger to battery lead positive terminal and one lead of the megger to aeroplane earth, apply test pressure for one minute.

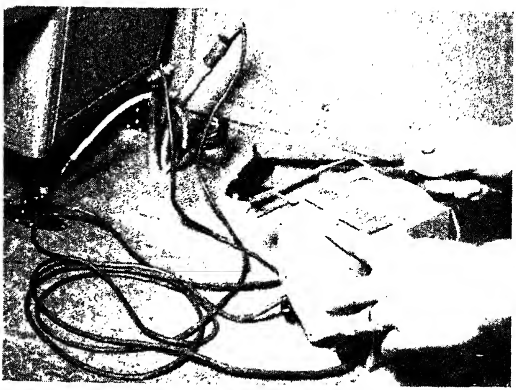


Fig. 6.—MEGGER TEST.

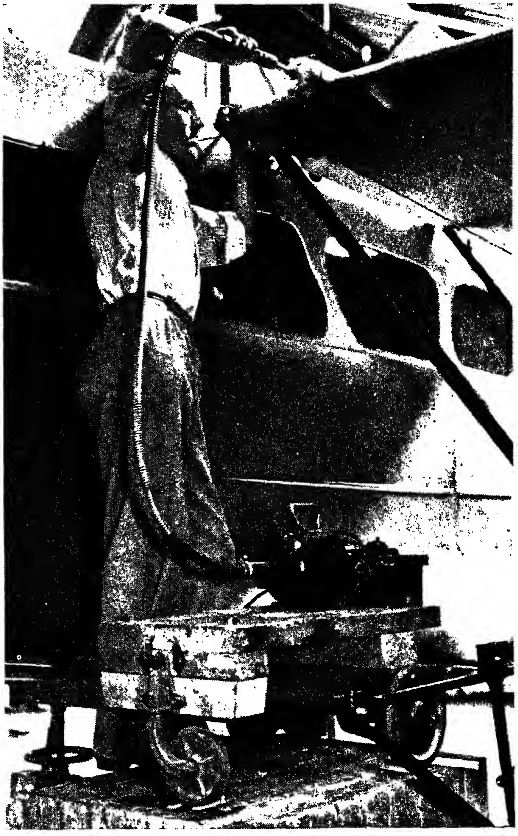


Fig. 7.—GENERATOR TEST RUN.
(Ground testing generator with portable motor.)

Test 3—" Negative Pole to Earth "

Connect one lead of the megger to battery lead negative terminal and one lead of the megger to aeroplane earth and apply test pressure for one minute.

The megger reading should remain steady and the value of resistance for tests 1, 2 and 3 is derived from the formula

$$\frac{20 \text{ meg. ohms}}{\text{No. of points}}$$

in circuit, each component or terminal block counting as one point, with a minimum of 2 meg. ohms.

Although the minimum of 2 meg. ohms is given, on a new installation the value should be considerably higher than this. Any low reading should be investigated, making due allowance for prevailing humidity of the atmosphere.

On successful completion of the preceding tests, replace all lamps and connect up components disconnected for the megger test. Open cut-out points and switches. Connect up a charged battery of correct voltage and operate each circuit in turn by the appropriate switches. Run the generator at correct speed and check charge and switch control and cut-out operation. Stop generator and check cut-out for correct operation and for excessive reverse current registered on the ammeter.

CONSTRUCTION AND ADJUSTMENT OF MAGNETIC COMPASSES

By WING-COMMANDER G. W. WILLIAMSON, O.B.E., M.C., M.Inst.C.E., M.I.Mech.E., M.I.E.E.

EVEN in these days of blind flying with gyro instruments, the pilot's eyes will be very frequently on the magnetic compass. After all, any free gyro may wander, and this wandering might be considerably increased without the pilot's knowledge in circumstances where some small thing may have gone wrong with the mechanism.

Such a fault might arise from dust in the bearings, as when a course has to be flown through some tropical sand-storm; or venturi tubes and pipes might become blocked with ice or condensation; or in thunderstorms the aeroplane may be forced into an attitude which would temporarily throw free gyro instruments out of action.

The magnetic compass will continue to function accurately in all these troubles; it is not subject to wander, being the only direction-seeking instrument borne in an aeroplane; and except when an aeroplane is struck by lightning, the magnetic compass remains reliable.

For these reasons, pilots come to depend upon its direction-seeking property and unless the magnetic compass is accurate they may be thrown many miles off their course on a long flight as a result of an error of only two or three degrees.

Construction of a Compass

It is not proposed here to deal in detail with the different types of compass used in aeroplanes; but it will be necessary for maintenance personnel to be aware of the interior arrangements of the instrument and reference to a proportion of the internal parts cannot be avoided.

It should first be explained that the majority of the compasses listed by the firms, especially those made for the Royal Air Force, are referred to by numbers usually prefixed by the letter P or the letter O; P indicates a compass for use by a pilot, and O, one intended for an observer who may be responsible for taking navigational sight readings.

All compasses prefixed by these letters have been designed by the Admiralty Compass Observatory. All Service compasses, as well as a large proportion of other aeroplane compasses in use in this country, are of the type styled aperiodic; but compasses used for other purposes than air navigation may be of the non-aperiodic type.

Supposing that one of these non-aperiodic compasses, with its needle pointing to the north, were disturbed to a 45° reading and allowed to

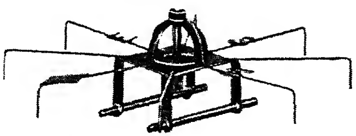


Fig. 1.—MAGNET SYSTEM OF HUSUN APERIODIC COMPASS.

swing back to the north point; unless special arrangements had been made to prevent such a result, the needle would swing nearly 15° beyond the north point and would continue to swing back and forth in decreasing arcs until in due course it came to rest.

An aperiodic compass, on the other hand, so disturbed would return as far as the north point, and would not swing beyond it, coming to rest in less time. Aperiodicity is secured in Service compasses by a strong magnetic moment, small inertia and heavy damping. In addition the magnetic system is provided with a number of damping filaments which set up eddies which damp the movement without impeding it or affecting the accuracy. Fig. 1 shows the aperiodic magnetic system of the well-known Husun type of compass.

To save constant definitions, a diagram has been provided which will show the principal parts of a pilot's compass. Fig. 2 lists every component of a pilot's compass and the dial of the same compass is shown in Fig. 3.

It will be seen that the magnetic system illustrated in Fig. 1 is carried in a cup H, in the bowl L, which is filled with liquid in order to provide a damping effect. At one time, a large bubble had to be left when the compass was filled, in order to allow for expansion and contraction of the liquid, but this was replaced first by a diaphragm and later by what is styled a sylphon tube expansion chamber. This is shown diagrammatically at O in Fig. 2; while an illustration of it also appears at Fig. 4. The bowl is carried inside a container fixed to the aeroplane, shown at Y of Fig. 2 and thick sponge rubber pads shown at V insulate the bowl and compass system from the vibrations which would otherwise be transmitted to it.

At one time, all compasses carried beneath the base a cylindrical box drilled so that a series of small magnets could be inserted at various angles to the magnet system of the compass itself. This cylindrical container was styled a corrector box and compensating magnets were inserted in these holes so that by their effect on the magnet system above them, they could compensate for any unavoidable inaccuracy due to the circumstances and surroundings in which the compass had been installed.

The use of a corrector box will be referred to later, but in a compass such as a Husun P.6 illustrated in Fig. 4 a far more convenient form of correction has been incorporated.

This valuable accessory is styled a micro-adjuster. Like the corrector box, it contains a series of magnets in the fore and aft line of the aeroplane and another series in the athwartships direction. Instead of taking

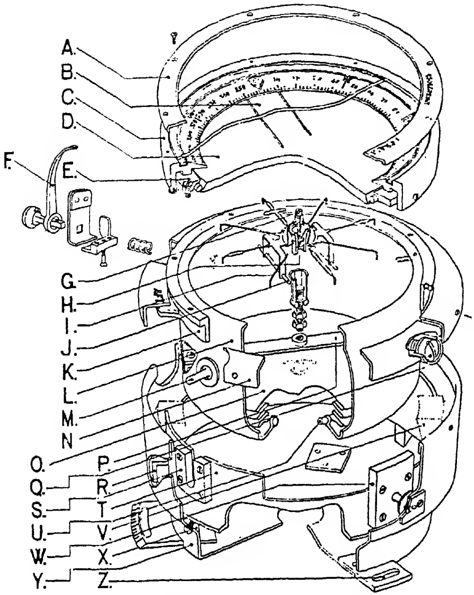


Fig. 2.—DIAGRAM OF TYPE P.6 COMPASS.

A. Clamp ring.
B. Cover glass.
C. Grid ring.
D. Verge glass.
E. Verge ring.
F. Grid ring clamp.
G. Pivot.
H. Cup.
I. Damping wires.
J. Magnets and frame.
K. Bowl ring.
L. Bowl with lubber line.
M. Guide pin.
N. Lid ring.
O. Sylphon tube.
P. Bridge.
Q. Filler plug.
R. Angle bracket.
S. Guide.
T. Floating ring.
U. Gasket.
V. Sponge rubber.
W. Guide.
X. Support for floating ring.
Y. Container.
Z. Securing lug.

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magnets in and out, adjustment of the compass (dealt with later) is carried out merely by turning the adjuster in a clockwise or anti-clockwise direction. This is illustrated in Fig. 5.

Installation of a Compass

In modern aeroplanes, it will in all probability never be necessary for the position of the compass to be fixed by anyone except the maker, and in Service aeroplanes this will be done in conjunction with the Air Ministry. Both the makers and the Air Ministry representatives will be aware of the additional equipment, later to be added to an aeroplane, which may have an effect upon compass accuracy. It follows therefore that under no circumstances should maintenance personnel permit, without checking the compass, of any addition to the aeroplane such as a Verey pistol in its holder, a metal map case or box for other equipment.

The position of the compass will already have been fixed as stated above, but it must be ensured that in its installation no iron or steel bolts and screws are used.

As with other instruments, it is necessary that the aeroplane should be placed in flying position. The compass is then fixed to its platform so that the instrument is horizontal, unless of course it is of the vertical

type as illustrated in Fig. 6. No part of the aeroplane must come into contact with the bowl of the compass and if as in Fig. 3 the word AFT appears on one side of the bowl the compass should be so placed.

The micro-adjuster shown in Fig. 4 forms part of the compass and will not need to be separately installed, but if a separate corrector box is supplied, it must be placed with its centre immediately below that of the compass, with the fore and aft magnets, usually marked by a painted line, correctly in the fore and aft line.

In the bowl of the instrument there is marked a line which must be in, or parallel to, the fore and aft line of the aeroplane; this painted mark is styled a lubber line. The lugs of the base are provided with curved slots so that these adjustments may be made when required by a slight turning of the compass in azimuth.

Tests for Serviceability

When a compass arrives for installation in an aeroplane, it must be remembered that it has undergone a considerable amount of handling on its journey by road or by rail from the works of its maker. Either before installation or prior to proceeding to swing the aeroplane, it is usual to make a series of simple tests to determine its condition as regards serviceability. The same tests can be applied at any time during the life of the compass, as when it is necessary to ensure that it is still in satisfactory condition after, for example, a heavy landing.

It is first tested for pivot friction by placing the aeroplane in flying position, noting the reading of the compass, and then deflecting the magnet system through about 5° by placing a corrector magnet near the compass bowl at right angles to the magnet system; when this corrector magnet is removed, the magnet system will swing back again; if it comes to rest exactly in its original position the compass is free from pivot friction.

A small amount of friction often exists, and if it is found that the magnet system comes to rest 1° to 2° away from its original position, the compass bowl should be tapped with the finger. If the magnet system then returns to its original position the compass is serviceable. When friction in the magnet system has been discovered in this way, the pivot has obviously become damaged. This repair can only be undertaken by experts and the compass should therefore be returned to the makers for attention or, if a Service compass, to the appropriate Stores Depot for transmission to the Admiralty Compass Observatory.

If a bubble should form in the compass liquid, it may be removed as follows:

The compass bowl should be withdrawn from its container, the grid or verge ring should be taken off and the bowl turned with its filling plug uppermost. The plugs should then be removed and the expansion chamber carefully distended by pulling on the eyelet provided at the bottom of the compass bowl.

Fig. 3.—HUSUN P4 APERIODIC COMPASS.

Pure alcohol of at least 0·84 specific gravity, without the admixture of any water, should then be inserted through a small funnel, the filling plug replaced and tightened up, care being taken that the washer is correctly in place. The tension should then be removed from the expansion chamber and the compass replaced in its outer container and the verge ring refitted.

Should a very large bubble appear it is probable that the compass bowl is leaking. In this case, refill the bowl as above; if the bubble persists in recurring the compass should be returned to the makers.

If the locking arms cease to function properly, they may be removed by taking out the small screws provided and moved backwards one place on the square head of the locking screw, then refix by reinserting the keeping screw.

Grid wires which have become slack may be tightened up by turning carefully the small slotted nut at the end of the grid wires with a split screwdriver specially made to fit.

These verge rings should be free to move easily. If a ring does not move freely it should be removed, cleaned and slightly lubricated with a small quantity of vaseline.

It must be clearly understood, however, that while it is generally a simple matter to carry out the above tests and repairs, no repairs to the interior parts of the compass bowl should be attempted. These repairs can only be undertaken by trained workmen and any attempt by other workmen might result in extensive damage to the compass.

Examination and Tests of Compasses under Air Navigation Directions

In Civil Instrument Specification No. 9, a series of requirements has been laid down for compasses to be carried in civil aeroplanes. The directional error of the magnet system must not exceed 1° and in England the tilt, with the north end down, should not be more than 2°; if the bowl is tilted to an angle of 15° the magnet system shall still be free to revolve; when a deflection of 10° is applied to the system by means of the corrector magnet as above described the friction error shall not exceed 1° at a normal temperature of 15° C.

Other tests can be applied to determine the time of swing; a 90° deflection is applied and then released so that the magnet system can swing back to the true heading; the time of that swing through the first

85° must not be less than 6 seconds. If the magnet system is similarly released from rest at a deflection of 30°, the overswing beyond zero shall not exceed 4°.

Fig. 4.—MICRO-ADJUSTER COMPASS CORRECTION.

One of the disadvantages of a compass bowl in which the magnet system is damped by means of a liquid is that in certain manœuvres when the bowl is rotated, the liquid itself may be carried round with the bowl and so deflect the compass system. This is most likely to happen during changes of course; a ground test can be applied by rotating the bowl through 180° during a period of thirty seconds. The deflection of the magnet system by this rotation shall not exceed 10° and the time of return to within 5° of the true reading shall not exceed fifteen seconds. If the bowl is rotated 180° in fifteen seconds, the deflection shall not exceed 20° and the time to return to within 5° shall not exceed thirty seconds.

In compasses which are not new, discolouration of the inside of the bowl may have occurred, due to the alcohol in the bowl attacking, amongst other items, the rubber sealing gasket. If there is sufficient clouding of the liquid to make the reading difficult, the compass may be considered unserviceable; in any case, with any discolouration of the liquid, pivot friction tests should be applied, in order to ensure that sediment may not have found its way into the pivot cup.

The diagram at Fig. 2 shows that the bowl is supported in its container by sponge rubber pads. Particularly in tropical climates these may deteriorate; the vibrations of the aeroplane may then be transmitted to the magnet system, causing irregular and inaccurate readings. This deterioration may be tested by moving the compass slightly backwards and forwards, first in a fore and aft direction and then athwartships. It is essential that so tested the bowl does not come into contact with the container. Under the Civil Specification referred to above, the compass can be tested by subjecting it to a horizontal vibration of any frequency up to 2,000 cycles per minute and a total amplitude not exceeding 0·2 mm.

Care of Compasses when Stored

Compasses not in aeroplanes must always be handled very carefully and must not be subjected to any shock. They should be removed from their standards, if of the observer pattern, and kept in boxes in the correct stowage position. It is essential that they should never be placed anywhere near electrical apparatus or where they would be within a powerful magnetic field such as that which might surround cables carrying a heavy current.

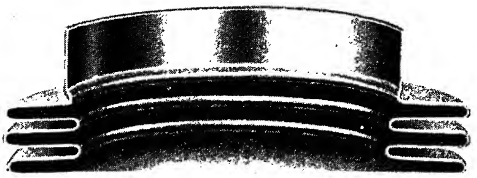


Fig. 5.—SYLPHON TUBE EXPANSION CHAMBER.

They should be examined periodically to ensure that they are maintained in a serviceable condition and must always be stored in such an attitude that the magnet system is perfectly free to revolve.

Use of Landing Compass or Compass Base

Aeroplane compasses may be adjusted as a result of tests carried out in the air, but it is here proposed to deal only with the methods of ground testing. They are as follows :

(i.) Using a compass base marked out on the aerodrome by a qualified navigation officer.

(ii.) Using a landing compass on a tripod of the type illustrated in Fig. 7.

If a compass base is available the aeroplane is placed along the lines marked out on the concrete, and various readings taken and compass adjustments made. With a landing compass, the observer stands exactly behind the aeroplane at a convenient distance and aligns the sighting device up the centre line of the fuselage. The sighting eye-piece and wire foresight can be seen in Fig. 7. Alternatively the landing compass may be set up in front of the aeroplane instead of behind, when its readings will be the reciprocal of those indicated on the aeroplane compass.

In some ways it is quicker to use a landing compass than to swing the aeroplane, especially if it is a large one, on a compass base. On a base, a number of small adjustments to the aeroplane may be necessary in order to get its centre line exactly along each line marked on the base. But with a landing compass it is only necessary to place the aeroplane approximately on the line of the main compass points and by sighting along its centre-line with a landing compass as previously described to determine its exact magnetic bearing. Thus the aeroplane need not be headed exactly due north for the first reading ; should its uncorrected compass reading be 4°, the landing compass will show whether this is the correct heading, or if not, what is the error at an approximate north.

The compass base, selected by a qualified officer, will in all probability be entirely free from magnetic disturbances. But in these days of rapid aerodrome construction its layout should be checked with a landing compass if new steel framed buildings are erected within say 100 yards ; similarly, a light railway track, and in particular electric cables, might

also result in disturbance, while the mere stacking of steel work close to the base, even though only temporary, would probably result in an appreciable deviation, the extent of which can be measured by a landing compass.

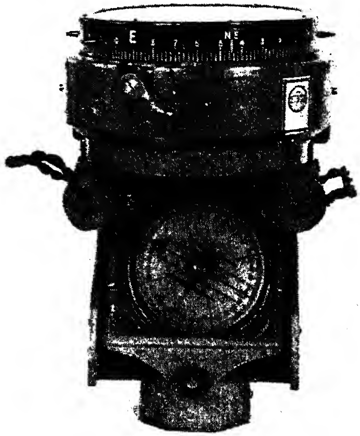


Fig. 6.—Husun P7 vertical compass.

Routine Inspection Prior to Compass Swinging

It should first be ensured that the compasses are in every way serviceable by applying the tests previously outlined. It would be a great waste of time, for example, to complete the swinging of a compass and then to find that it would be unserviceable for pivot friction or discoloration.

The collector box or micro-adjuster must be properly fitted with its centre immediately below the centre of the base. It is usual to begin with the fore and aft line of the corrector box exactly in the fore and aft line of the aeroplane, but whether the compass is to be lined up on a compass base or by means of a landing compass, the corrector box or other compensating device may have to be temporarily removed.

It is essential to remove all equipment which is not carried in flight, such as tools, corrector magnets, etc. and it is equally important that the aeroplane shall be fully equipped with anything normally carried in flight which might affect the compass. In this class will fall not only the guns, signalling pistols, photographic equipment or W.T. apparatus, but electrical circuits which if switched on might result in deviation of the compass. The aeroplane must therefore carry all its batteries.

Routine of Compass Swinging

In aeroplanes which may have several compasses, correction on each should be made before the aeroplane is moved to a different heading.

Electrical circuits will be switched on and off on each heading to ensure that they do not affect the final reading on that compass point. Wires carrying current are usually twisted together to give a neutralised field.

With each change of heading, compasses should be given time to settle down to the new reading; this may be assisted by gentle tapping of the compass bowl.

Fig. 7.—HUSUN LANDING COMPASS WITH TRIPOD.

It is usual, either using compass base or landing compass, to hang plumb-bobs from the centre of the airscrew boss and the tail skid in order to facilitate alignment. The aeroplane should be in flying position.

Swinging the Compass for Correct Alignment

When the compass has been newly installed in an aeroplane it requires not only compensation for any permanent magnetism in the metalwork of the aeroplane, but also to be correctly lined up. These two adjustments are quite distinct and it is proposed to deal first with the correct alignment.

The compass is held in position by screws passing through three lugs attached to the housing, the screw-holes being slotted circumferentially to permit of an adjustment in azimuth of 5°. One lug is engraved in degrees over an arc of 10°. The purpose of this is explained below.

The compass is first fixed with its lubber line pointing, as nearly as can be judged, in the fore and aft line of the aeroplane. All magnets are removed from the compensating block and placed at a sufficient distance so that they produce no effect on the compass.

The aeroplane is then positioned with its fore and aft line on N, E, S and W (magnetic) successively, compass readings being noted in each position.

The compass reading is taken by first turning the grid ring until the N point of the divided circle corresponds with the arrow head of the needle system, and the grid wires are parallel with the N–S direction indicators; then reading the angle indicated by the lubber point (attached to the bowl) on the divided circle of the grid ring.

(By turning the grid ring until parallelism occurs and the N point of grid corresponds with the N point of the needle system, the divided circle is in the position that would be occupied by a graduated card attached to the magnet system in the manner of a navigational compass.)

The compass readings on N, E, S and W are then added together. The summation will be of the order of 540 or 900 according as the value for the N position is nearly 360 or nearly 0.

For example, if there were no errors, one would have

N	0	360
E	90	90
S	180	180
W	270	270
Summation	540	900

Having obtained the summation, the rule is: take the difference between it and 540 or 900, as the case may be, and divide this difference by 4. This value is the number of degrees that the compass must be slewed round in azimuth for correct alignment. If the summation be less than 540 (or 900 as the case may be) slew in the clockwise direction; if the summation be greater, slew in the anti-clockwise direction.

EXAMPLE 1.

Aeroplane,	N	(magnetic).	Compass reading	347
,,	E	,,	,,	93
,,	S	,,	,,	186
,,	W	,,	,,	262
			Summation	888

This is 12 less than 900, hence slew compass 3° clockwise by means of the graduated arc on the fixing lug above mentioned.

EXAMPLE 2.

Aeroplane,	N	(magnetic).	Compass reading,	12°
,,	E	,,	,,	86°
,,	S	,,	,,	173°
,,	W	,,	,,	277°
			Summation	548

This is 8 more than 540; hence slew compass 2° anti-clockwise.

Swinging Aeroplane Compass—Compensation for Permanent Magnetism

The first adjustment for correct alignment having now been made, proceed with magnetic compensation.

The aeroplane is again headed N (magnetic) the tail lifted and the compass reading observed. If it is not reading 0 (it would not in the above examples), it is because there is some permanent magnetic attraction due to the magnetisation of some iron or steel work in the aeroplane. A magnet is then slipped into one of the thwartplane holes of the compen-

sating block. If the error be increased, the magnet should be removed and turned round with its blue end where the red end was previously. The effect of such a magnet on the compass will be increased by putting it in a higher hole and reduced by putting it in a lower hole. If one magnet is insufficient, a thicker one, or two magnets, can be used.

Having found the correct combination of adjusting magnets, so that the compass now reads 0, the aeroplane is slewed round to head S (magnetic) when the needle should still point parallel with the grid wires. (On resetting the grid ring the lubber line will read 180° on the divided circle.) Should there be any error, the magnets may be adjusted so that the error is equally distributed between the two positions with the aeroplane pointing north and then pointing south. Having obtained the best compensation on north and south, the aeroplane is then headed east, and the process repeated, using on this occasion the holes in the compensating block which are drilled in the fore and aft direction.

Reverting to the examples already cited, in the first case, after slewing the compass, the readings would be

N	350
E	96
S	189
W	265

Now a magnet which increases the reading at N will decrease it by the same amount at S and *vice versâ*. The same applies to a magnet increasing or decreasing the reading at E; it produces an equal decrease or increase at W. Hence a magnet or combination of magnets in the thwartplane holes which makes the reading 0 on N, will make it 179 on S; magnets neutralising the error on E, making this 90, would make the reading on W to be 271. This would be a very good adjustment.

Taking the second example cited above :—

After slewing the compass, the readings would be

N (magnetic).	Compass reading,	10°
E ,,	,,	84°
S ,,	,,	171°
W ,,	,,	275°

Compensating magnets are inserted so that the reading on N is, say, 1° when the reading on S will be 180°; magnets in the fore and aft direction are inserted so that the reading on E is, say, 89° when that on W will be 270°. This again will be a very good adjustment.

Having finally determined the location of the compensating magnets, they are locked in position by the securing strips attached to the compensating block.

It is then as well to take compass readings on the eight cardinal and quadrantal points, jotting them down on the deviation card. These

readings are the "*courses to steer*" for the corresponding true magnetic directions.

Thus :

True Magnetic Direction.	*Course to Steer.*
N (magnetic)	
N.E.	
E.	
S.E.	
S.	
S.W.	
W.	
N.W.	

The deviation card should be fixed in some convenient place in the aeroplane where it can be easily read by the pilot.

Acknowledgments

Acknowledgments are due to Smiths Aircraft Instruments, Cricklewood Works, London, N.W.2, for Figs. 1 to 7 and also for the notes under the heading of "Tests for Serviceability"; to Kelvin Bottomley & Baird Ltd., Cambridge Street, Glasgow, for the wording of the paragraphs on swinging compasses for alignment and compensation, and to Mr. Arthur Hughes, O.B.E., A.F.R.AeS., of Henry Hughes & Son Ltd., for suggesting several improvements in this section.

FACTORY INSPECTION METHODS

By R. H. Longe, *Inspector, Saunders-Roe, Ltd.*

IN the first place the duties of the airframe and engine inspector are to ensure that the ideas and designs developed in the design and drawing offices are correctly embodied in the structure or unit.

Whilst he is doing this, he must also ensure that all requirements are complied with as laid down in Air Publication 1208 and Air Navigation Directions No. 13 and Amendments.

Inspection is a vital link in the chain of production from the raw material to the completed airframe or engine and evidence of this is necessary at each stage before passing to the next. Strictly speaking, the inspector should reject any detail or assembly which does not comply with drawings or requirements, but he sometimes finds that a certain amount of discretion is necessary to avoid undue scrap—for example : a pin or bolt may be given a plus/minus tolerance of ·002 in. on diameter, but not be highly stressed when assembled into the unit. If, say, 100 of these bolts have been machined and show minus ·005 in. on diameter, they could be cleared for use with Stress Office approval. A knowledge of the use to which the detail in question is to be put is essential when deciding a case such as this.

The duties of the inspectors can be divided into groups, *i.e.*, detail inspection, inspection of processes such as heat treatment, protections, etc., material testing, incoming stores, sub-assemblies, covered components and final erection and testing.

Check on Material

To enable a check to be kept on all material used, a definite system must be arranged. The material is received at the constructors under cover of a " Release Note," which states that the material or component in question complies with the requirements of A.N.D. as regards quality or manufacture. These Release Notes are issued by the firm concerned under an Authority Reference No. and each has a serial number.

The material is checked into the bonded store and an internal release or batch note is then issued on which is quoted the original Release Note No. The material is also marked in such a way that it can be readily identified.

Job Card

When an issue is made to the shops of material from this batch, a job card is issued, on the back of which is noted the material and batch number of the latter. On completion of the detail, it is cleared and

R N WOODS LTD NO 5146

A PHIR HOUSE

LONDON N.10

RELEASE NOTE DATE 21-8-37

THIS CERTIFICATE IS ISSUED UNDER A/M AUTHORITY REF 123456/7

TO J JONES LTD YOUR ORDER NO 513

EARLS COLNE

ESSEX

SUB CONTRACT ORDER NO 43772

FORM 536 REF NO 781 ORDER COMPLETE YES NO (DELETE ONE)

THE FOLLOWING GOODS HAVE BEEN DESPATCHED TO YOU BY POST

QUANTITY	SPEC	DESCRIPTION	DRG NO	TEST REPORT	REMARKS
2	C I S/4	ENGINE SPEED INDICATOR	22471	40378	

CERTIFIED THAT THE ITEMS ENUMERATED HEREON HAVE BEEN WHOLLY MADE FROM APPROVED MATERIALS, THAT THEY CONFORM TO THE APPROPIATE DRAWINGS & SPECIFICATIONS & THAT THEY HAVE BEEN INSPECTED & APPROVED IN ACCORDANCE WITH THE REQUIREMENTS OF THE DIRECTOR OF AERONAUTICAL INSPECTION & THE CONDITIONS OF :-

(A) AM FORM 705

(B) AIR NAVIGATION DIRECTIONS (DELETE ONE)

SIGNED [illegible]

ON BEHALF OF R.N.WOODS

Fig. 1.—THE RELEASE NOTE.

J JONES LTD BATCH NO 1434

INTERNAL RELEASE NOTE

RECEIVED FROM	DATE	SUB CONTRACT ORDER
R N WOODS	23-8-37	43772

TO A I D ½ THE FOLLOWING GOODS HAVE BEEN SUBMITTED FOR INSPECTION AND THOSE ACCEPTED HAVE BEEN PASSED INTO APPROVED STOCK:-

SPECIFICATION	QUANTITY	DESCRIPTION	REMARKS
DTD 63	5—1 GALL CANS	ALUMINIUM LAQUER D 510/30L	
DTD 62A	5—1 GALL CANS	SYNTHETIC PRIMER SB 590	
FOR 2 D101	3—1 GALL CANS	ANTI CHILL THINNERS T.24	

RELEASE ISSUED BY	NUMBER	DATE	SIGNED [illegible]
VENDORS	5137	9:8:37.	WORKS INSPECTOR

DATE 24-8-37

TO WORKS INSPECTOR

SIGNED

DATE

Fig. 2.—THE INTERNAL RELEASE NOTE.

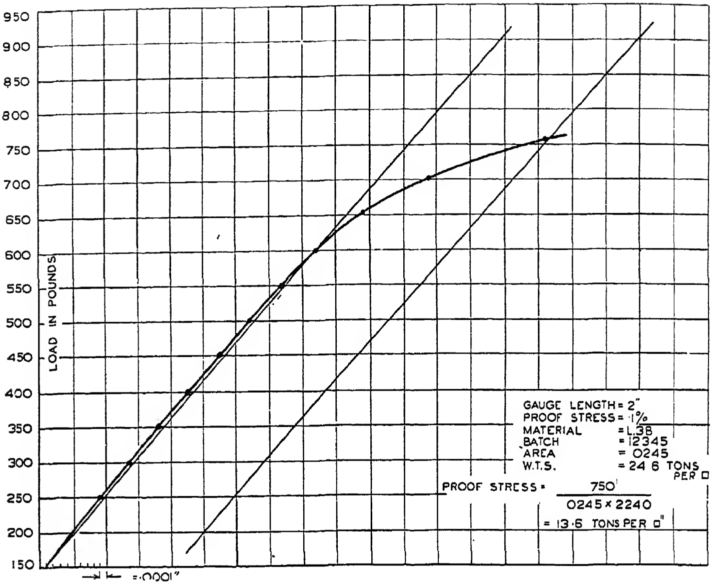


Fig. 3.—GRAPH SHOWING THE 0·1 PER CENT. PROOF STRESS.

stamped by the inspector and the card is filed for future reference, if the latter is found necessary.

The detail may pass back into finished stores and be drawn out at a later date for embodiment in the airframe or engine. To keep the chain of identification complete, the batch number is clipped to the detail and, on being issued to the shops, a note is made on a card of the serial number to which the detail is being fitted.

The job card issued in the shops will also carry evidence of any heat treatment necessary after working, to give the required strength, such as normalising with welded mild steel fittings, hardening and tempering of D.T.D.60.A or final heat treatment of duralumin bar or sheet.

Drawing Corrections

It was mentioned in the first place that the inspector's duty was to ensure that the work was to the approved drawings. Cases sometimes arise, however, when errors are found in the drawings themselves. For example, a fuel pipe may lie too close to some part of the exhaust system or the angle of a lever may be incorrect. In cases such as these the inspector

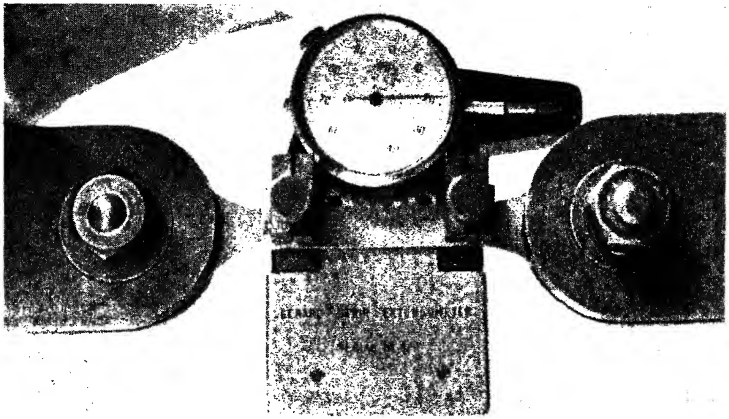


Fig. 4.—The extensometer.
An extension of 0·020 in. is shown under a load of 750 lbs. The material is L.38.

should note these points before the work progresses too far and see that the necessary drawing corrections are made.

Whilst on the question of drawings, obviously the latest issue will be worked to where possible, according to the class of the modification.

A.N.D. states that "all components and details must be made to approved drawings," therefore it is not permissible to copy a detail when replacements are being made. A drawing must be worked to in all cases, with the following exception :—

A clause in A.N.D. states that a temporary repair may be made to an airframe or engine to enable it to be flown to some place where a proper repair can be carried out. In such a case as this, however, the necessary entry is made in the log book and the aeroplane must not be used for hire or reward purposes.

"Concession" or "Error Acceptance" Sheet

Cases often arise when a large batch of details or sub-assemblies have passed through a number of operations before an error is found. Providing this error does not seriously affect the details when incorporated in the assembly, they may be passed through for use by means of a "concession" or "error acceptance" sheet. The latter must be kept by the inspector and filed for reference. If the error exists in a detail already embodied in the aeroplane, the registration letters or number should be given on the concession sheet in question.

Fig. 5.—THE IDENTIFICATION COLOURS PAINTED ON THE RAW MATERIAL.

The material used in this example is D.T.D.111.

Raw materials, such as sheet, strip and bar, are received under the manufacturer's release note, which indicates that it has been checked for compliance with strength requirements and chemical composition. No further check is necessary unless it is subjected to heat treatment, when a test specimen must be supplied from that batch.

Light alloys such as L.24 are tested by running a test piece at each pouring, this being machined to dimensions laid down in the specification and tested in the normal way. If the castings are highly stressed, they must be individually proof loaded and radiologically examined.

Streamline section tubes employed for struts and stays are checked for cracks or flaws particularly at the leading and trailing edges. This applies more especially to stainless steel tubing to Specification D.T.D.105.

Most material in sheet form has a plus and minus tolerance on the gauge and this is checked to ensure it is within limits. The limit is usually 1 gauge.

Fig. 6.—INSPECTION OF DETAILS.

The holes should "hold up" the "NOT GO" gauge.

An identification colour scheme is employed to distinguish the various metals and takes the form of one or more colours painted on the sheet or bar. This assists in easy location of any one specification.

The inspector must ensure that finished components received from a sub-contractor, such as engines, airscrews, oil coolers, accumulators, bracing wires, etc., are maintained in an efficient manner to prevent deterioration whilst in stores. Air Publication 830 lays down the principles of this maintenance. The same remarks apply to sub-assemblies and covered components. The latter should be placed

in racks in such a way that their shape is retained and no load is taken by light members in the structure.

Inspection of Details

Inspection of machined or built-up details is important, to avoid holding up erection of the complete airframe or engine. The latest issue of drawings should be used for this purpose. In addition to a check on dimensions, the radii at bends and under the shoulders of machined fittings should be carefully checked and screw threads must be within the limits laid down. The outsides of all bends are also inspected for signs of cracks.

Mild Steel Fittings

If the fitting is built up of mild steel such as S.3 or has been welded, it must bear evidence of having been normalised and if of the same material, not welded but having been turned over or flanged, it must bear evidence of tempering. The stamps "N" and "T" are used for the purpose. All inspection stamps, etc., must be impressed clear of drilled holes and away from bend radii. The temperatures for S.3 are, normalising at 860° C. and tempering at 450 to 500° C.

Duralumin Fittings

Fittings machined or built up of duralumin must also be normalised to relieve stresses and the muffles or salt baths employed for this purpose are checked periodically by an inspector to ensure that the maximum temperature of 500° C. is not exceeded. They should also be anodically treated.

In the case of "Y" alloy, this maximum temperature is 520° C.

Materials requiring both hardening and tempering to give maximum strength such as D.T.D.60.A are to be stamped in a similar manner to S.3.

Tensile Test

The three most common tests carried out by the inspector are the tensile, hardness and impact tests.

With regard to the first, it is usually sufficient to determine the proof stress figure, although, in the case of a new material, the percentage of elongation, reduction of area, yield point and maximum tensile strength are also determined.

Hardness Test

The hardness or Brinell test is more convenient for check purposes on finished details, as the latter is still serviceable after the test. The result of this test, however, does not show fully the qualities of the material. The Brinell number, when multiplied by a constant, gives the ultimate tensile strength approximately only. It may be employed for checking purposes on case-hardened details.

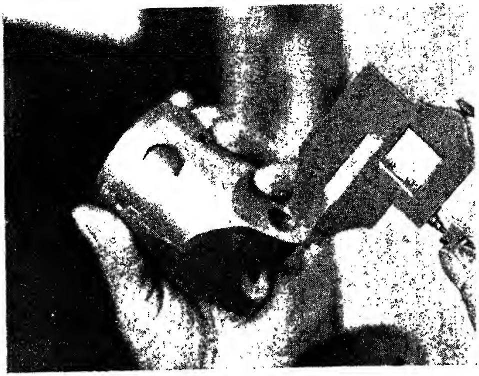


Fig. 7.—INSPECTION OF DETAILS.
The radius around the hole is important.

Impact Test

The Izod or impact test is used to determine the ductility of the material and is used considerably for tests on certain details.

The various woods are also checked by this method.

When making a Brinell test, care must be taken to ensure that the detail being checked lies flat on the table, otherwise a false reading will be obtained.

Jigs and Templates

These will be checked by the inspector before passing into the shops for use. Great care is necessary to avoid scrap due to errors in the jig or template, and it is advisable to have a detail made from them for check purposes. On proving satisfactory, the jig or template is stamped by the inspector.

Fig. 8.—INSPECTION OF DETAILS.
The radius under the heads of eye bolts, etc., must be checked.

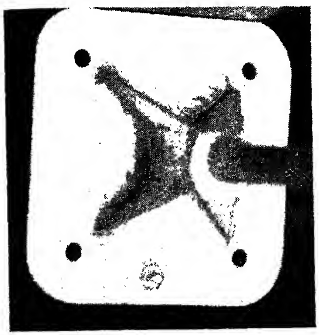


Fig. 9.—SHOWING EVIDENCE OF NORMALISING AFTER WELDING.

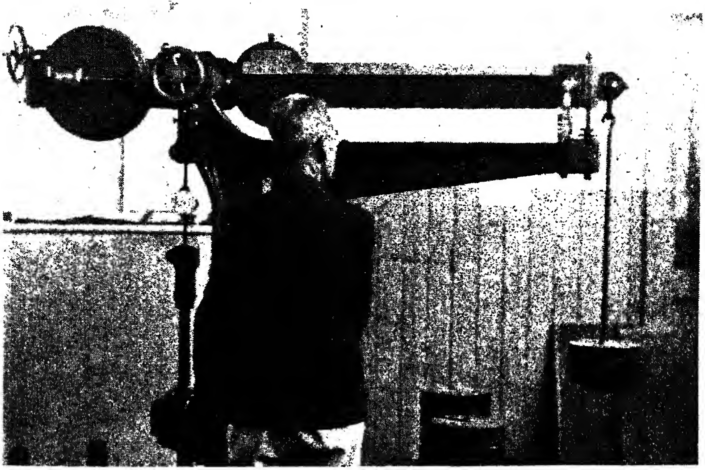


Fig. 10.—THE MANUALLY OPERATED TENSILE TESTING MACHINE.
A parachute release box casting is being proof-loaded to 2,000 lbs.

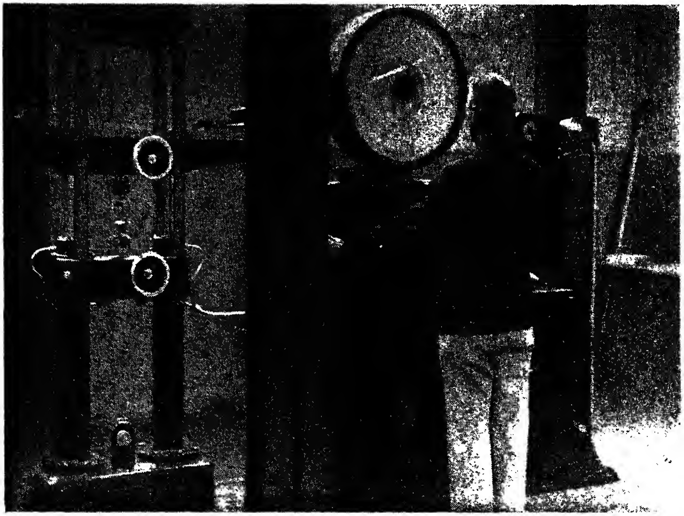


Fig. 11.—THE HYDRAULIC TENSILE TESTING MACHINE.

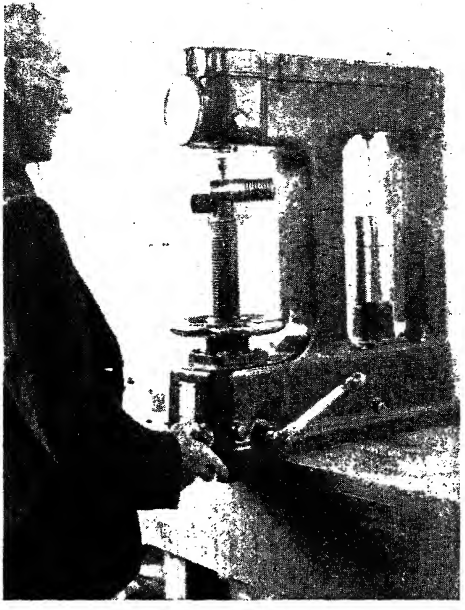


Fig. 12.—THE HARDNESS TESTING MACHINE.
Showing the machine in use.

Details such as struts and stays having detachable fork ends are checked for bottoming of the tube in the fork ends. An inspection hole must be provided for this purpose.

Welding

The inspection of welded joints and fittings is necessarily restricted owing to the fact that the only effective method of inspecting them is to cut through the weld and check the fusion through this cross section. This method, of course, will render the detail useless. Only officially approved welders must be employed on aeroplane details.

An instruction leaflet lays down the tests to be carried out before a person is approved as a welder and the method of checking these test pieces.

Periodical checks should be made to ensure that the correct welding wire is being used, and that dissimilar metals are not being fused together. A visual inspection of the joint should show freedom from blow-holes, fine cracks and freedom from deformation of the detail in the region of the weld.

In the case of light alloys, the detail must be thoroughly washed after welding to ensure removal of all flux. If this is not done, rapid corrosion will set in and pitting will occur should the detail be anodically treated.

As previously stated, a welded detail should be normalised according to the specification of the material, but this is not always practicable, as, for instance, a welded engine mounting or tubular steel fuselage. In cases such as these, allowance is made as regards the strength of the unit by calling for a sufficiently heavy gauge of tube to counteract the fall in strength due to welding.

Certain steels are most suitable for welding, such as S.3, D.T.D.41, and are in the low carbon group. Others are not and the detail job card showing the specification of the material being used should be checked when the job is being inspected. An elementary knowledge of these steels is essential.

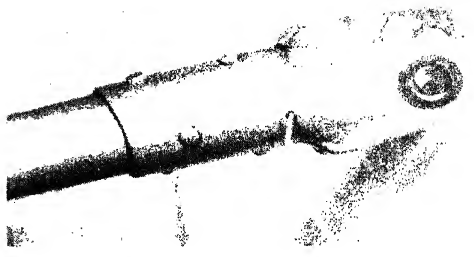


Fig. 13.—SHOWING THE INSPECTION OF THE TUBE IN ITS FORK END, FOR BOTTOMING.

Heat Treatment, Etc.

The baths or furnaces being used for heat treatment purposes should be periodically checked for temperatures and a book record kept. The type of pyrometer employed is of the thermo couple type and a periodical check should be made of all instruments against a master pyrometer.

Anodising is carried out on the light alloys and should be visually inspected for pitting and chromic acid stains. A rough check can be made by means of an indelible pencil. On damping the surface of the detail and rubbing it with the pencil, the dye should be retained when an attempt is made to rub it off with a piece of rag.

A more stringent test is made by checking the electrical resistance of the surface of the metal.

Cadmium and other forms of protective coatings are visually inspected, the processes being occasionally checked to ensure cleanliness and that the best results are being obtained. These protective coatings will tend to be porous if the time and current voltage are not in accordance with standard practice. As the coating is purely for anti-corrosive purposes, it is desirable that the particles of metal should lie close together and resist penetration by air or water. The thickness of the coating can be checked by means of a test piece inserted in the bath with a batch of details being treated.

In the case of anodic oxidation the inspector must ensure that the chloride content of the water being used for making up the chromic acid solution is not above a certain figure (0·2 grammes per litre). This can be done by sending a sample to a test house or analyst.

Covered Components

Fabric covered components are inspected thoroughly before the cover is fitted. The structure itself must bear evidence of inspection up to that

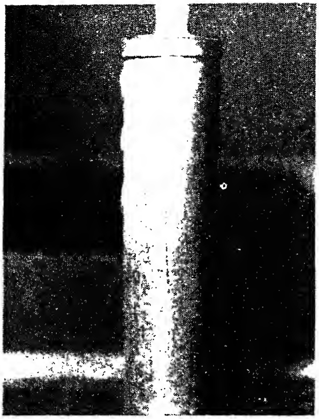


Fig. 14.—SHOWING HOW FINE CRACKS IN STRUT TUBING DEVELOP IN SERVICE.

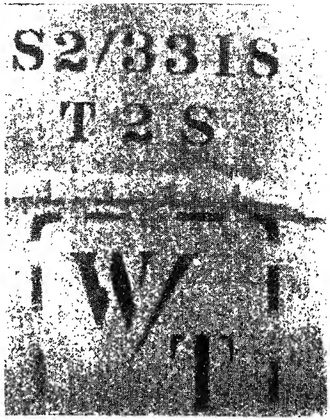


Fig. 15.—THE SERIAL NUMBER, DOPING SCHEME AND W/T MARKING ON A COVERED COMPONENT.

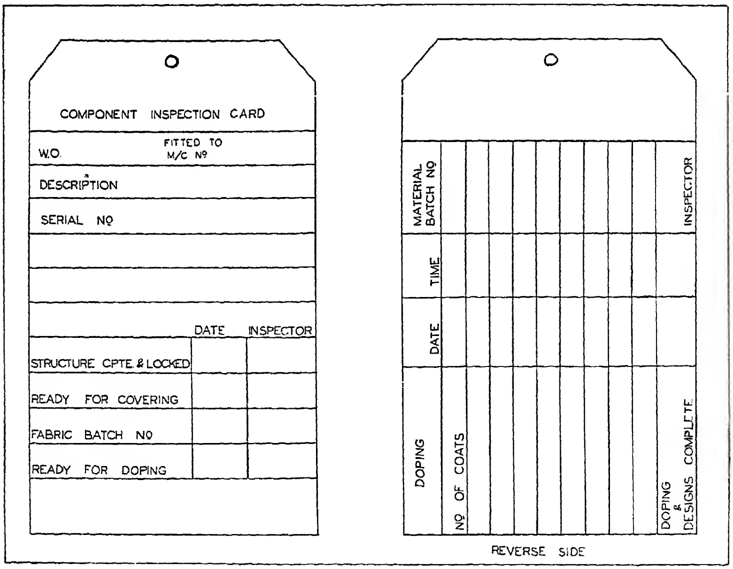


Fig. 16.—THE COVERED COMPONENT INSPECTION CARD.

stage and must also carry a serial number for identification purposes. If the structure is of wood or of composite construction, it is becoming standard practice to "bond" it whether W/T is being carried or not. This obviates undue opening up of the covering should W/T be fitted after the aeroplane passes into service. This bonding should be checked for low resistance.

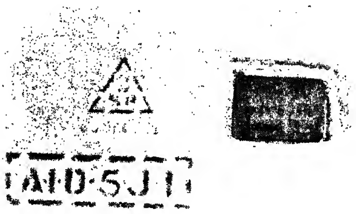


Fig. 17.—THE WINDOW GIVING ACCESS TO THE SERIAL NUMBER AND INSPECTION PLATE.

Terminals must be supplied at the junction of the component where it meets an adjacent part of the aeroplane. The structure will be inspected thoroughly for soundness of glued or welded joints, fittings for security and seating, all bolts and pins for being tight and locked and bracing or swaged rods for being in correct tension, being in safety and all lock nuts tight. Where bracing wires cross one another, they are prevented from chafing by means of Systoflex, fibre sleeves or other similar means.

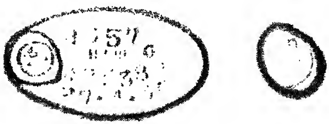


Fig. 18.—FIXING THE INSPECTION AND SERIAL NUMBER PLATE TO STRUTS AND STAYS.
Showing the method employed.

A card should be attached to the component bearing the serial number and this should be signed by the inspector at the various stages, such as, cleared for covering, ready for doping and the number of coats, with the batch number of the materials used. It should also carry the serial number of the airframe to which the component will be fitted. The card is afterwards filed for reference.

Where control cables are carried inside the structure, it should be noted that there is no danger of their touching any part of the latter, even when

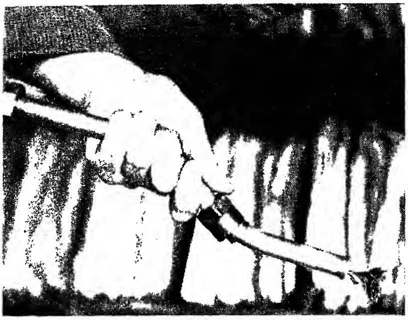


Fig. 19.—INSPECTION OF PIPES.

through " and thoroughly

they are inclined to be unduly slack. This condition may exist when the aeroplane is flying in rough weather. The control cables should be held tight at both ends and the lead on to the cable pulleys noted for being central between the pulley flanges. All bolt and pin heads should be uppermost where possible.

The standard scheme must be worked to for taping ribs in deep section main planes and the protection of sharp edges, bolt heads, etc. The tape or fabric employed, however, must first be doped before being used to prevent any retention of moisture and so avoiding corrosion.

The covering, after being sewn on, is inspected for being moderately tight, all seams running fore and aft and being straight.

Deep section structures are strung under the rib booms only, but in the shallower sections the stringing is taken completely round the rib and in the latter case the inspector must watch that the stringing is well clear of all flying control cables.

The position of the serial number and inspection plate having been noted before covering, the fabric is cut away at this point and a celluloid window sewn in its place.

Fig. 20.—INSPECTION OF PIPES.

must be free

The doping of the unit is then proceeded with according to the scheme being employed. An occasional check is made to determine the weight or quantity of dope applied by having a test piece fixed to a small frame and being doped at the same time as the component. The correct weight of dope applied should be $3\frac{1}{2}$ ounces per square yard of fabric.

After completion of the

doping, the inspector places his stamp and the date close to the serial number plate, noting that the serial number has been stencilled on the cover together with the doping scheme, such as T.2.S.

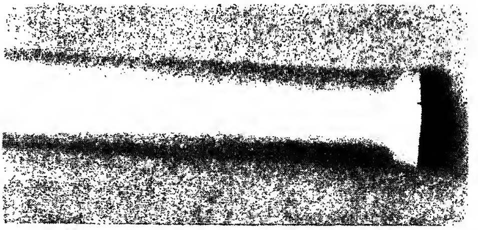


Fig. 21.—INSPECTION OF PIPES.
Belled ends of pipe lines should be free from cracks.

The dope room temperature should be checked daily when doping is in progress. This should be 70° F. The humidity must also be checked by means of a wet bulb thermometer.

An important point to watch with covered components is the provision of adequate drain holes. These must be perfectly clear and not obscured by dope or pieces of fabric. When hoods are fitted to these drain holes, they should leave the hole completely clear and should be in streamline. The holes themselves should be as close to the trailing edge as is practicable so as to prevent corrosion of the trailing edge tubes in the case of metal structures.

Oil and Fuel Tanks

Oil and fuel tanks are first inspected as details, that is, the baffles, end plates, etc., are checked for shape and material and suitably stamped by the inspector with a progress stamp. Dimensions are important to avoid distortion when fitting the baffles into the shell of the tank. Flanged lightening holes are checked for cracks, these being found more frequently in tanks built up of light alloy. Whether the tanks are of tinned steel or anodically treated light alloy, they must be free from scratches and scriber marks and all burrs must be removed from rivet holes. If a drill is used to remove these burrs, it should be observed that the rivet hole has not been countersunk when doing this.

Fig. 22.—INSPECTION OF PIPES.
Porous brazing, as shown here, should be rejected.

A card should be attached to each tank and bear an inspector's signature for each stage in its construction.

It is becoming increasingly popular to employ a light alloy for tank manufacture, riveted by the De Bergue method. Each rivet should be individually checked for correct

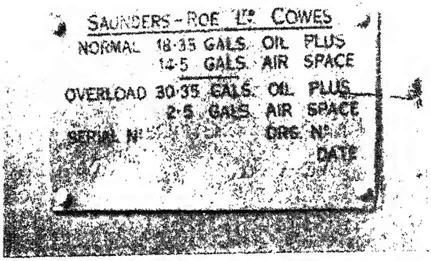


Fig. 23.—The oil tank.
Showing the plate which is attached to the tank.

formation of the head. An excess of jointing material should not overhang the inside of the joint as this may eventually disintegrate and choke the filters or carburetter jets.

Before the tank is closed it must be inspected for being scrupulously clean. Where possible all details such as sumps, cover plates, jettison valves, etc., should be fitted before pressure testing. The tank should be pressure tested to 1½ lbs. per square inch for subsequent productions. This can be done by coating a nts with a paste of whit
and water or methylated spirit and allowing
then placed in the tank to cover the floor
applied. The tank should be

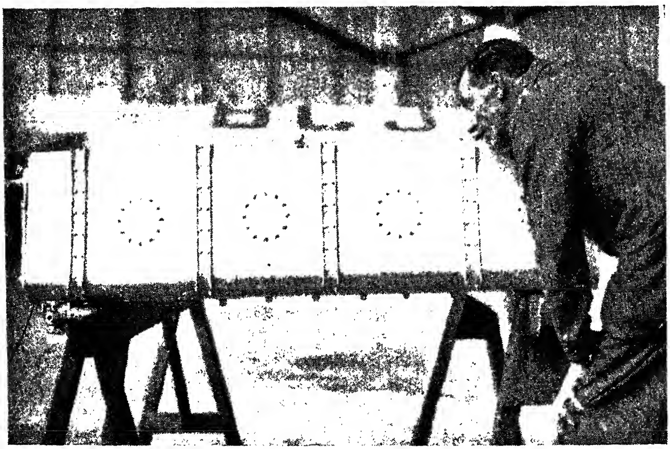


Fig. 24.—The oil tank.
holes in the bearer feet by means of thread.

The capacity of a tank is only checked when it is a "type" tank or when the inspector has cause to call for a check test. This should not show a variation from the drawing capacity of greater than plus/minus 2 per cent.

A serial number plate must be attached to each tank giving the following particulars :—

Fuel or oil.
Drawing number.
Capacity.
Air space (if any).
Serial number.
Inspection stamp.
Date of manufacture.

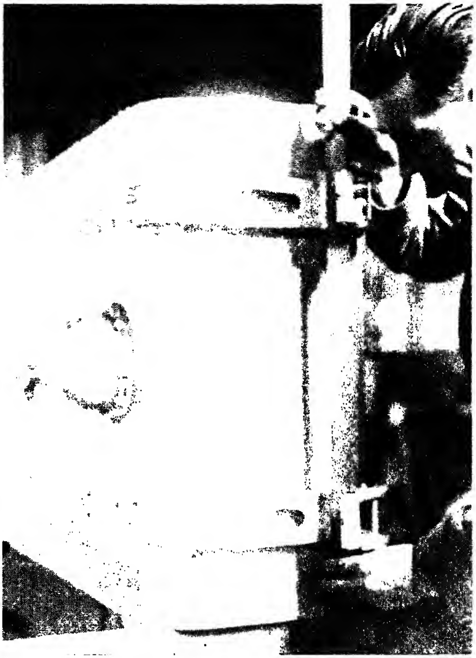


Fig. 25.—THE FUEL TANK.
Checking the truth of the support feet.

The tank bearer feet must be checked for interchangeability and also for security.

In the case of tinned steel tanks, all rivets must be tinned before being used and care must be taken that no blobs of solder are allowed to hang from sweated seams. These will break off in service and cause obstruction in the supply line.

Tanks of this type must also be washed thoroughly with hot water to remove any traces of flux residue.

If the tanks are not being immediately installed into an aeroplane all open connections should be blanked off before storage. The inspection cards will be filed by the inspector. Such details as junction boxes must also be pressure tested. The figure should be given on the drawing and is usually 50 lbs. per square inch.

Copper pipe lines are not pressure tested after being made up, but those of stainless steel must be tested to 50 lbs. per square inch. The inspector should check carefully all belled and beaded ends of pipe lines for signs of cracks or marks caused by the belling tool. Every pipe must be pulled through and washed to ensure freedom from foreign matter.

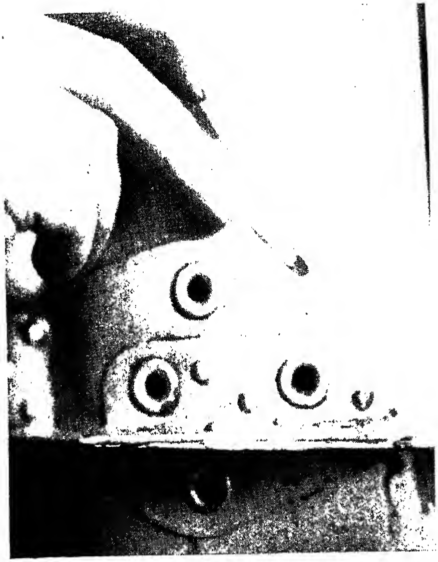


Fig. 26.—THE STRUTS.
These are checked to see that they are a snug fit in their sockets.

Bends in these pipe lines are checked for being free from kinks and also for being free from "flattening."

Each pipe line should carry a tab giving its part number and the inspector places his stamp on a blob of solder alongside this tab. The pipe lines should then be varnished or lacquered and the ends sealed.

The inspection of such structures as the fuselage or hull, the main planes and tail unit, is too large a subject to be dealt with here, but a few remarks ... on this subject b... leaving it.

The majority of fuselages are jig built and the details, such as longe... vertical and transverse members, are all inspected before being emb... in the structures. The fuselage is again inspected after assembly and checked for truth in the usual manner.

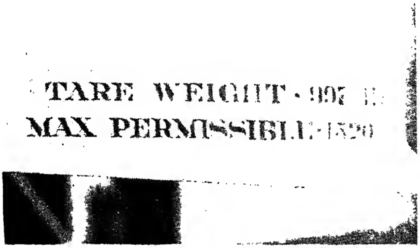


Fig. 27.—SHOWING THE TARE AND MINIMUM WEIGHTS WHICH MUST BE STENCILLED ON THE FUSELAGE OR HULL.

In the case of a hull, the keelson and frames are also inspected and passed by the inspector as details and these are also made to jigs. The keelson is then placed on its saddle and the frames positioned at their correct stations. This is checked before the plating is attached. The main plane attach-

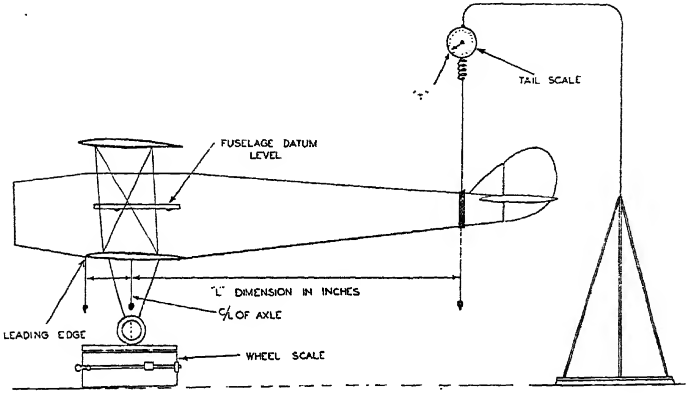


Fig. 28.—DETERMINING THE LONGITUDINAL CENTRE OF GRAVITY.
Showing the dimensions to be taken.

ments on both fuselages and hulls are checked for dimension and interchangeability, this being a very important point. The tail plane attachment fittings and the stern post are also checked. The tail unit structures are usually made to jig and will be checked and inspected in the same manner as the main planes.

Components such as a hull in which riveting is largely employed are checked over after plating to ensure that all lap seams are closed up and that the riveting is satisfactory. Drainage at all points must be effective and all parts of the structure protected by means of paint or oil varnish of an approved nature. Tubular members such as spar booms, etc., should be protected internally by some approved method, such as Sozol or oil varnish.

Inspection of Final Erection

More than one inspector is usually employed on final erection, one perhaps dealing with the airframe and its controls, another with the engines and their services, and a third with the equipment, such as electrical, W/T, etc.

WIEGHT AND C.G. RECORD

INSPECTION DEPT
J. JONES LTD.

RECORD OF WEIGHING G-BFAD IN TARE CONDITION AFTER INSTALLING WALTER POLLUX II R ENGINES —

HULL DATUM LEVEL		HULL DOWN 10° AFT	
WEIGHT AT PORT SCALE :	3075 LBS	AT PORT SCALE :	2912 LBS
" " STAR " :			2916 "
	521 "		836 "
TOTAL	6664 "	TOTAL	6664 "
℄ OF AXLE TO TAIL SUPPORT =	24′ 6 7/8″	℄ OF AXLE TO TAIL SUPPORT =	24′ 11 5/8″
" " " " LEADING EDGE =	1′ 10 1/4″	" LEADING EDGE	
∴ C.G =	45·13 AFT OF LEADING EDGE	C.G =	44·55 AFT OF LEADING EDGE

THE FOLLOWING EQUIPMENT INCLUDED IN THIS WEIGHING

2 PYRENES & BRACKETS	FUSE BOX
BILGE PUMP & HOSE	BOAT HOOK & LINE
MOORING MAST	DUAL CONTROL
3 SWASH BOARDS	2 STARTING HANDLES
2 PILOTS SEATS & CUSHIONS	TOWING PENNANT
ENGINE & AEROPLANE INSTRUMENTS	BRAKE SYSTEM
2 SAFETY BELTS	2 VENTURI HEADS
REMOTE CONTROLS (W/T)	GENERATOR & AIRSCREW
TUBE, DEXINE	2 GENERATOR MOUNTINGS
" WATERTIGHT	
KEY (W/T)	NO FUEL OIL
AMMETER	NO ANCHOR

SIGNED

Fig. 29.—A TYPICAL WEIGHT SHEET.

All details embodied in the aeroplane must bear evidence of previous inspection.

During the fitting of the main plane or planes to the fuselage or hull, the inspector should observe that no undue force is required to tap the attachment bolts home into their fittings. The rigging of the aeroplane is usually checked first; if it is a monoplane, this will be a fairly simple matter. The incidence and dihedral will be checked and the main plane checked for being square with the hull by measuring from the nose or bow to a point on each wing, equidistant from the centre line of the fuselage or hull. The same check will be made to the tail or stern. The tolerance on these dimensions will naturally vary according to the size of the aeroplane. These limits are sometimes exceeded with no effect on the directional path of the aeroplane in flight. Discretion must be used in such cases as this.

Although the rigging of the aeroplane is passed by the inspector as being within the stated limits, it is often found necessary after the first test flight to make adjustments to the main plane incidence or the fin setting. A record should always be kept of these alterations. In the case of monoplanes, provision is usually made for fitting a trimming strip on one of the ailerons, for the correction of flying one wing low, this also being recorded.

The inspector should keep a record of all readings taken on the

rigging as these will be entered on Form 1221, when the aeroplane is completed.

All wires are checked for being in streamline and safety and suitably protected where they cross one another. Wiring plates or lugs are sighted for taking the load through their centre lines and not being offset to the wire.

Engine Mountings

These will be checked over in the manner indicated in "Inspection of Engine Installations and Services," taking note that the various requirements are complied with as laid down in A.P. 1208.

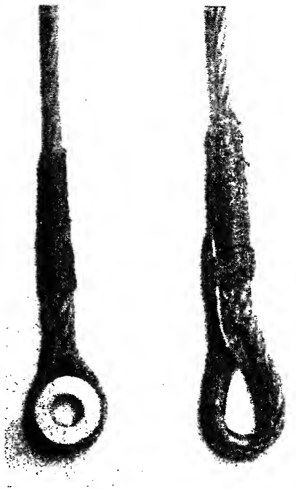


Fig. 30. — SHOWING THE METHOD OF TREATING SPLICES IN EXTRA FLEXIBLE CABLES.

Flying Controls

The flying control system on the aeroplane must be given a dual inspection by two separate individuals, the second inspection being made when all work is complete. No one should be working on the latter when this is being carried out. All cables, brackets, pulleys, rudder-bar units, control columns, etc., are inspected and passed as sub-assemblies before being installed and should bear evidence of this.

The direction and range of travel are checked and a record made of the latter. The control cables must be proof loaded to 50 per cent. of the maximum strength and chains to one-third. The inspector must witness this test and check all splices for being made in the approved manner.

Cables made up of wire other than non-corrodible should be soaked in hot linseed oil for protective purposes and the ends of splices neatly served. The tab carrying the inspector's stamp is secured to the splice and not allowed to float along the wire. Each run of cable is checked from end to end and the entry of the cable into the pulley groove checked for being square.

The fuel and oil systems are checked over in the manner indicated in "Engine Installations and Services," and a flow test taken at each carburetter. The system should be free from air locks before making this test and this can be ensured by allowing a certain amount to pass away from the outlet before making the test. The time taken for one pint to pass is sufficient on small installations, but the time taken for 2 quarts will give a more accurate check on the larger types.

Fig. 31.—THE TAB CARRYING THE INSPECTOR'S STAMP MUST BE SECURED TO THE SPLICE.

The above illustration shows what *happens* if this tab is allowed to float along the cable.

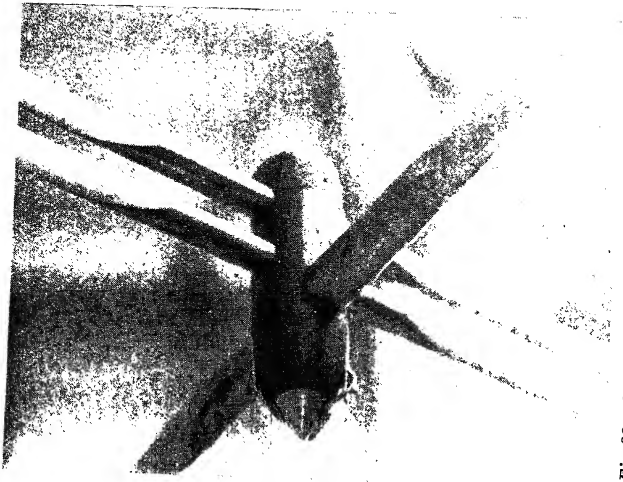


Fig. 32.—SHOWING ONE FORM OF BRACING WIRE ACORN.

This is employed to protect the wires from chafing.

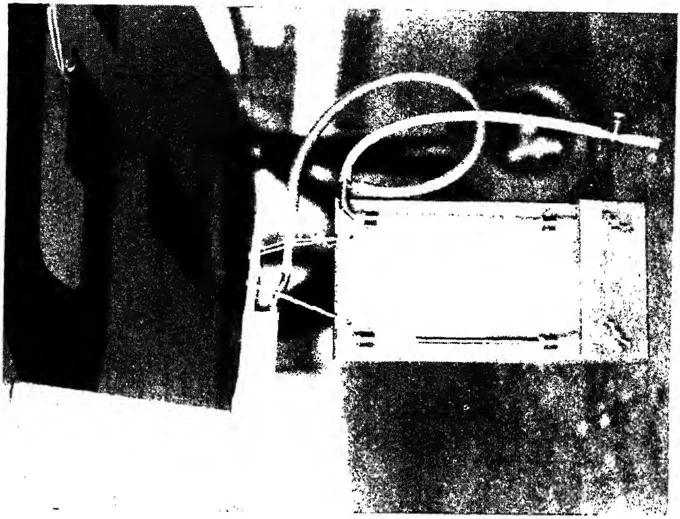
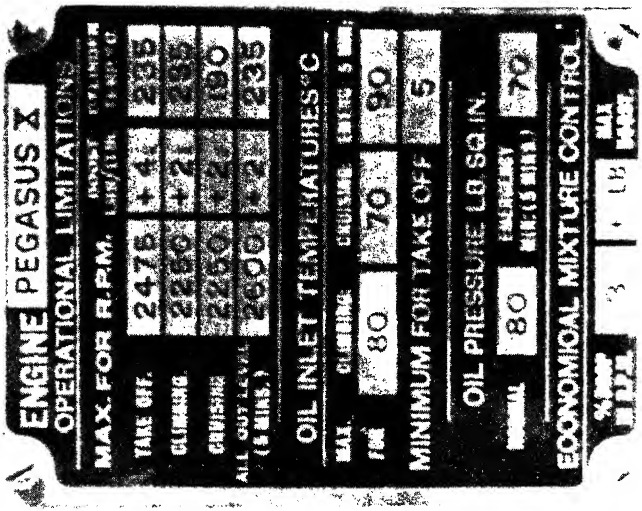


Fig. 34.—THE A.S.I. PRESSURE TUBE.
Showing the tube being tested for tightness.



ENGIN PLATE.
prominen osition in the

ENGINE RUNNING AND FLIGHT TIME

AEROPLAN

	PORT	CENTRE	STAR
ENGINE TYPE & SERIAL NO			
AIRSCREW DRG & SERIAL NO			
START			
TOTAL TIME ON GROUND			
" " IN AIR			
MAX REVS ON GROUND			
" " IN AIR			
BOOST PRESSURES			
OIL PRESSURE IN			
" " OUT			
" TEMPERATURE IN			
FUEL PRESSURE			
" SPEC & QUANTITY			
OIL " " "			

PILOT .... ROUTE

LOAD ....

REMARKS

SIGNED

Fig. 35.—THE FORM FOR RECORDING TEST FLIGHTS.

Undercarriage

The undercarriage is first checked for being square or equally disposed about the centre line of the fuselage and noting that all components bear an inspection stamp. Brakes when fitted are checked for functioning and for equal braking at both wheels. The brake operating system is checked for being tight whether of the hydraulic or the pneumatic type.

If the undercarriage is retractable, the operating gear is checked several times for functioning and any warning device or indicator must function normally. All axles are tested individually and the release note should certify this. The material largely employed for these details is T.2, a nickel-chrome steel, and no heat must be applied to them in the form of a soldering iron or other means.

E/L and W/T Services

These services must conform to the provisions laid down in Specification G.E. 164. The inspector should check through each circuit in turn and make a check on all services by means of a lamp and battery or by fitting the standard accumulator designed for that aeroplane.

A check is also made, by means of a 500 volt megger, on the electrical resistance of all leads.

A check is made on the system of bonding to ensure that the resistance of the bonds is low. The ignition system is checked at the same time for

continuity and correctness of wiring. A megger test is not made on this system.

Engine and Cock Controls

The methods of inspecting these were outlined in "Engine Inspection and Services." As with other systems, all details should bear evidence of inspection. Whether the controls are of the rigid or the flexible type, they should operate positively and freely with no fouling of any part of the structure.

Instruments

All instruments are first checked to ensure they are of an approved type. A record is taken of their serial numbers and these are checked off against their release notes.

In the case of oil pressure gauges and thermometers, the capillaries are inspected for being securely clipped and coiled at the engine ends. Boost gauge lines are pressure tested at 10 lbs. per square inch and air pressure lines, when fitted, to 200 lbs. per square inch.

The compass is checked for being correctly mounted, with the lubber line truly fore and aft. The bolts holding the compass should be of a non-ferrous material to avoid magnetic interference. The inspector should witness the correction of the compass and a correction card made out and placed in a prominent position where it can be seen by the pilot.

The A.S.I. must be calibrated and the pressure and static lines checked for being tight. The pitot head should be pointing squarely into the line of flight and suitably supported if carried on an extension arm.

Determination of Centre of Gravity

On completion of the aeroplane and the dual inspection of the flying controls, it should be weighed in the tare condition and the centre of gravity determined.

All fuel and oil tanks, also radiators, if the engine is of a liquid cooled type, should be drained and all normal equipment in position. The wheels are then placed, one on each scale, and the tail supported by a third. The sum of the readings at all three scales will be the tare weight, less any packing utilised to steady the aeroplane on the scales. The longitudinal centre of gravity is taken at the same time.

The aeroplane is checked for being level fore and aft and plumb lines are dropped from the leading edge on either side of the fuselage. A plumb line is also dropped from the centre line of the latter to cut the centre line of the axle. Another is dropped from the point of support at the tail.

The following measurements are then taken :—

Distance from the leading edge to the centre line of the axle.

The distance from the centre line of the axle to the point of support at the tail.

The formula to be worked to is :—

$\frac{T \times L}{W}$ plus the distance from the leading edge to the centre line of the axle, where :

T = the weight at tail.
L = distance from centre line of the axle to tail.
W = total weight of the aeroplane.

The result of this formula will be, so many inches aft of the leading edge. If the result is a negative quantity, the centre of gravity will be forward of the leading edge. (The leading edge referred to will be that of the lower main plane in the case of a biplane.)

It is not usual for the inspector to check the vertical centre of gravity, but if this is necessary, the same procedure is carried out again, but with the tail down 10°.

The vertical C.G. is then found by the formula :—

$$5{\cdot}75 \times \text{the C.G. at } 10^\circ \text{ down } \textit{minus } 5{\cdot}67 \times \text{the C.G. at fuselage level.}$$

The figure obtained will be the distance in inches above the chord line of the main plane.

The engines are then ground tested by the inspector and, if satisfactory, the aeroplane is cleared and test flown, any necessary corrections being made on its return.

Forms C.A.27 and 28, the airframe and engine log books respectively, are then filled in and Form 1221 completed and application made for the Certificate of Airworthiness.

It will be seen from this outline of inspection procedure that every means must be taken to ensure that all details are incorporated as the designer intended and that the aeroplane is absolutely airworthy before being passed into service.

PRODUCTION OF AEROPLANE INSTRUMENTS

By Wing-Commander G. W. Williamson, O.B.E., M.C., M.Inst.C.E., M.I.Mech.E., M.I.E.E.

PRACTICALLY all aeroplane instruments weigh less than 2 lbs. each, their light weight and small size provide production problems quite distinct from those met with in heavier aeronautical engineering such as aero engine manufacture or the construction of aeroplanes.

Many of the mechanical operations required are exactly the same, except that they are on a greatly reduced scale. Castings are required exactly as in the aero engine, their weight being measured therefore in ounces instead of in pounds; there is a tendency to produce as many cast parts as possible in material even lighter than aluminium. Machining is still necessary; the large majority of the lathes are either of the bench or the small instrument type, and milling machines as well as drills are usually of a size intended for installation on a bench or special pedestal instead of standing on the floor.

In addition to processes similar to those used in heavier engineering, a series of operations peculiar to instrument work has necessarily been developed. Many small parts of light metal are best produced by means of spinnings, provided that the surface to be spun is a circular one, that is, a surface of revolution. Ball bearings on a miniature scale are frequently used, although construction is no different from those required in heavy engineering; shafts of instruments may be required to move in jewelled bearings, which have no counterpart in mechanical engineering, other transmission may be by gearing or by the finest of nickel chain. Finally, diaphragms, whether silk or metal, capsules and Bourdon tubes, might be said to be peculiar to instrument work and to have no corresponding parts in aeronautical engineering generally.

Parts common to all Instruments

One glance at the dashboard of an aeroplane will show that many of the parts of the instruments are common to all and will therefore involve the same manufacturing processes. Every instrument is provided with a case, sometimes a die-casting and sometimes a moulding; the case has a glass front held in place by a screwed-on bezel; the glass may be provided with a washer made of paper or of rubber, and if the bezel is not of the screwed down type will be kept in place by a spring ring.

Turning to the interior of the instrument, almost every type finds a use for a movement involving one or more shafts and cross-shafts, sets

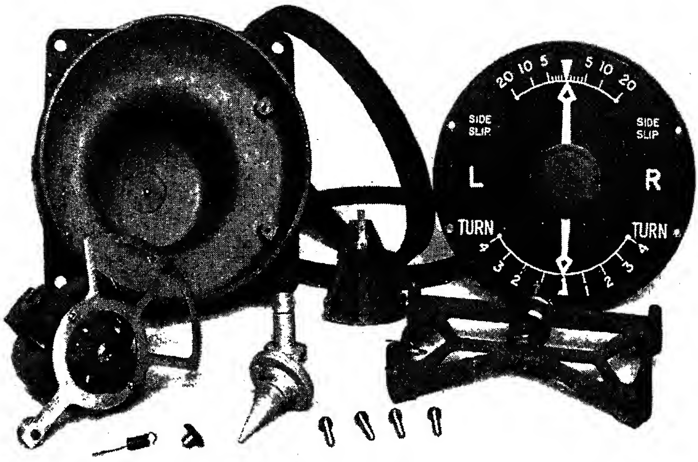


Fig. 1.—AN EXAMPLE OF A METAL CASE.
The illustration shows a turn indicator, dismantled into all its components.

of gears and pinions, and sometimes other forms of linkage connecting the operating component to the pointer.

The pointers of all instruments possess a family likeness not only in appearance but in the method used for their production ; nearly all scales are engraved upon thin plates of dural, anodised and enamelled. Scales are engraved, usually filled with a white compound, and the more important points of scale and pointer picked out with mesothorium-radium.

It is proposed to deal first with parts common to all instruments and then proceed to the various operative components which are peculiar to particular instruments such as turn indicators, altimeters, airspeed indicators and engine revolution indicators.

Cases

Cases of instruments may be die-castings, but in recent years Air Ministry specifications have insisted upon a gradual reduction in the use of metals and a replacement by mouldings. Nevertheless, many makers will provide an instrument, on request, either in a metal case or in mouldings, dependent upon the preference of the consumer.

If the case is metal, it is usually a die-casting ; such a case is shown in Fig. 1 ; this is a turn indicator dismantled into all its components. Very few instrument makers carry out their own casting or moulding. It is usual for die-castings to be supplied by a firm which has specialised in their production.

Admittedly, the case will have to be designed by the instrument maker; he will then send a drawing of the case to one or more of the die-casting firms, who will quote for its production in quantity. The price they quote is divided into two parts :—

(i.) A price per thousand die-castings above a figure of say, 5,000.
(ii.) A price for the construction of the tools required, such as the dies ;

this price may be the whole cost of the tool, in which case the tool becomes the property of the instrument maker, but is retained by the die-casting constructors ; the usual method is to charge half the cost of tools.

When satisfactory castings have been taken off, the contract for a number not less than a thousand may proceed. The castings are inspected at the works of their makers and again on arrival at the works of the instrument maker. Each consignment is accompanied by a release note identified in some way with the castings to which it refers.

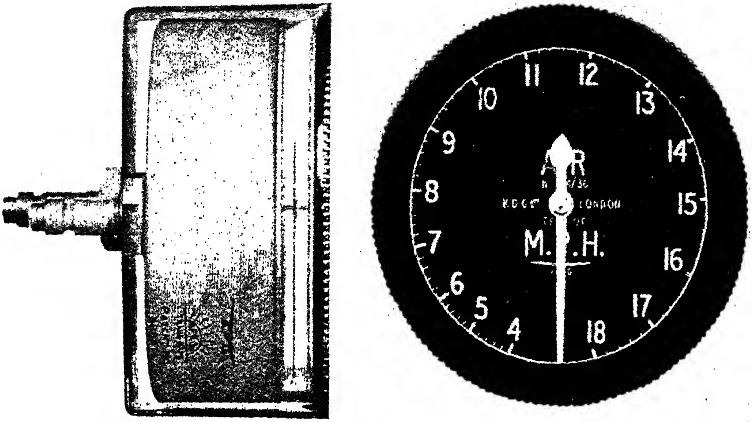
The metal for these castings is laid down in the Air Ministry specification for each instrument. This specification may not be departed from and special precautions are taken to ensure that each batch of metal received from the aluminium contractors is also accompanied by a release note, and is liable, like all other incoming aeroplane materials, to be inspected by the representative of the instrument makers. Until that inspection is complete, the metal, casting or other incoming material, is kept in a bonded store and may only be issued against a form of requisition which will ensure that at any moment in its passage through the shop, the batch from which the item has been taken can be instantly identified.

When the cases have passed through preliminary inspection, they are sent into the shop for any mechanical process such as drilling or machining. It may be necessary, for example, to mill the front face of the case so that when the glass and bezel is in position the case will be airtight ; milling may also be necessary for the seating of any part of the movement or operating mechanism ; screw holes will need to be drilled and tapped as required by the design of the instrument. If any lathe work is necessary, as for example, the chasing of the screw provided for the bezel, the instrument designer must either bear in mind the necessity for chucking or else provide special tools which will facilitate the necessary lathe work.

When machining is complete, it remains only to protect the metal case against corrosion which might form upon exposure to sea air or sea spray ; cases of aluminium or its alloys are anodised, and are finally spray painted, stove enamelled or treated in such a way that the still hot anodising absorbs a colour.

Mouldings

Moulded cases for all types of instruments are rapidly becoming more usual than metal cases, the latter being only retained for instruments



[*Korect Depth Gauge Co. Ltd.*

Fig. 2.—A MOULDED CASE AND TRANSPARENT LID.

which have necessarily been standardised in that form. The cost of the tools for such a die-casting is very considerable and it would therefore be expensive to change over to a moulding.

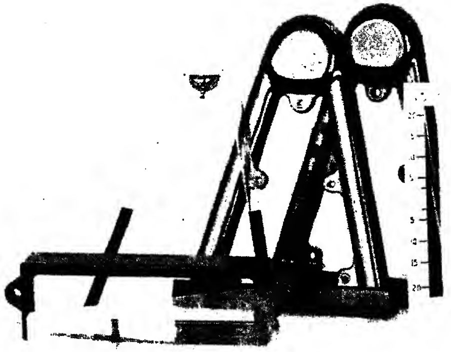
Neither in die-casting nor in moulding is it worth while making tools to a special design for an order which does not run into thousands. But when an order exceeds 10,000 and may be renewed annually or more frequently, the cost of the tools spread over the instrument orders becomes a steadily diminishing quantity and finally becomes so small that it may be regarded as having disappeared.

Just as with die-castings, mouldings must be made of materials specified by the Air Ministry, factors being taken into consideration such as strength and resistance to a knock or blow and non-inflammability.

Cases can be moulded in such a way that little or no machining is required and this will apply even to the provision of holes ready for tapping. Such a refinement would not necessarily be an economy unless the number on the order was very considerable. It will usually be found that most of the mechanical processes applicable to aluminium cases are also required on those supplied as mouldings.

Just as aluminium alloy castings may be anodised in varying colours in order to distinguish the various instruments, mouldings may now be carried out in various colourings. As only the bezel shows in front of the dashboard, the whole of the case of the instrument can be of some stock colour easily produced ; the lid or bezel can be in colours such as red, green, yellow or blue to distinguish, according to their special indications, instruments which in a bad light would otherwise look exactly alike.

Mouldings for instrument cases possess another advantage over instruments provided with metal bezels. The latter are usually fitted with a glass circle, but instruments have been shown faced with rhodoid or other perfectly transparent material, not nearly so breakable as glass. Where the lid portion of the instrument is a moulding, there is no reason why the transparent part should not be integral with the lid itself, and in production, this saves not only the separate construction of two or more items, but greatly improves the method of making the case of the instrument airtight, if this is, as is usual in many instruments, a matter of importance.



[*Reid and Sigrist, Ltd.*

Fig. 3.—THE FORE AND AFT LEVEL.
Showing the glass cover.

Where colouring of the bezel is not called for, the whole of the lid portion can be transparent; this has the advantage that the face of the instrument is illuminated through the transparent part of the case, instead of a deep bezel which may cast a shadow over an important part of the dial. The instrument can be held in place in the instrument board by a stirrup, so that there is a transparent annular behind the dashboard; floodlighting behind the dashboard then illuminates clearly these and other instruments similarly cased, ensuring that they are not only better illuminated, but free from glare and also from shadow. Fig. 2 serves to illustrate not only the general appearance of a moulded case, but also the transparent lid in question.

Cases for instruments need not necessarily be of the usual circular type and moulding lends itself especially to any light and small instrument produced in large numbers. Fig. 3 shows dismantled the component parts of a fore and aft level of a type made in thousands for the Air Ministry. Although the two mouldings which form the sides are identical and could be produced by one tool, in actual practice this would not be permitted, since one of them must have moulded upon its surface a reference to the Air Ministry specification; if the instruments are intended for R.A.F. use, the same moulded lettering will also include the letters A.M. and a crown.

Fig. 4.—THE REID GYORIZON. Showing also the glass bubble of another type.

For such an instrument therefore, there will be two tools for the sides of the body and a third for the lid. Very careful tooling and production are necessary to ensure that the two halves of the body will go together without the necessity for fitting, machining or filing and also that when the lid portion is placed in position its screw holes match up with those in the body.

Glass Parts

The faced instruments now protected by glass circles or rectangular shapes could equally well be provided instead with some transparent and less breakable material; but doubtless owing to its cheapness and the fact that the instruments for which it is required are being produced in very large numbers, glass continues to be the usual transparent cover of a large majority of instruments being manufactured. Before a moulded transparent material can replace it economically, machining operations and labour must be saved to an amount which will represent the difference between the cost of glass and the cost of the newer, less breakable, but more expensive replacement.

Very few instrument makers take the trouble to buy glass in bulk and cut it to the shape required. As circles or more rarely as rectangles, the glass is bought and the only operation upon it by the instrument maker is a careful cleaning and inspection to see that each circle is free from scratches or defects, is correct to specification and to the agreed tolerance.

Many of the instruments to which the glass will be fitted must be airtight and a circle will in all probability be seated upon a rubber washer; as stated previously it may be kept in position either by a screwed down bezel or a circlip.

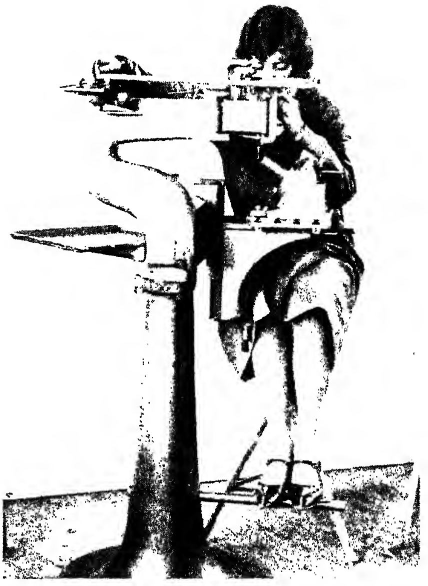
Quite a different type of glass part is found in various instruments using blown glass, as for fore and aft levels and cross levels. In Fig. 4, the bubble of a cross level appears; and Fig. 3 shows the fore and aft level. This work is a highly complex operation and when glass bubbles are ordered, the blower is responsible that they are to specification and also that they are filled with the correct liquid.

Filling Liquids

Filling liquids for aeroplane instruments may be to various specifications, depending upon the purpose for which they are required, but all of them must fulfil one important condition: they must not change in any

way due to temperatures as low as minus 60° C. Where filling liquids are stained black or red, they must not stain the glass tube in which they are carried even if left in one position for many months; on the other hand, if left exposed to light for a similar period, they must not change colour.

The two glass bubbles, each filled with the appropriate liquid, are shown in Fig. 3 and Fig. 4. Another sample of a filled component —the liquid cross level of the Reid Gyorizon is also shown in Fig. 4.



Taylor, Taylor & Hobson, Ltd.

Fig. 5.—THE MACHINE USED FOR ENGRAVING DIALS.

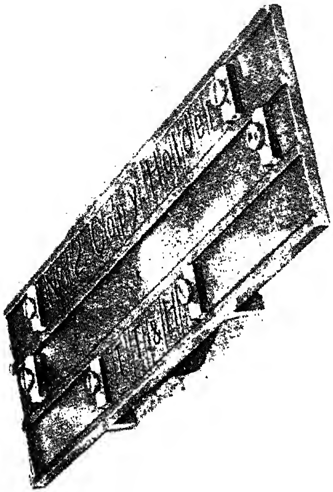
Dials

Most dials consist of circles of dural, stamped out by the hundred from large sheets. The gauge is usually sixteens, but one or two thicknesses depend upon the preference of the maker or the provision of the specification. After inspection for quality of metal, dimensions and truth, they are sent forward for engraving.

Dials are engraved by a machine of the type illustrated in Fig. 5; standard dials being turned out in hundreds or thousands and are engraved from a master plate, a sample of which is shown in Fig. 6. The operator follows the lines on the master plate with a stylus; this motion is reproduced in the movement of a revolving tool, which passes over the surface of the circular dural blank, cutting out the lettering.

If a small number of dials are to be cut, such as those which may be required for a limited number of instruments in a foreign language, a pattern can be specially made up from the alphabet supplied; if the lettering is of a type not found amongst European alphabets, the dial must be drawn, enlarged to the size of the pattern and marked out in such a way that outlines to be engraved can be followed by the stylus. An example of this type of engraving is given in Fig. 7, which shows the dial of a Smith airspeed indicator intended for Iran.

The next process is the stove enamelling of the engraved blank; if



[*Taylor, Taylor & Hobson, Ltd.*

Fig. 6.—A MASTER PLATE, IN COPYHOLDER FORM.

the instruments are for the Air Ministry, the enamel must correspond to a stated specification and samples will be inspected by the A.I.D. All dials have a hole in the middle through which the pointer shaft passes. Each blank can be mounted upon a revolving table and sprayed uniformly with the enamel as the table rotates. Usually, there is a jig or fitment upon which a large number of dials can be sprayed at once; arrangements are made so that they can be lifted without being touched by hand and then placed in the drying oven.

The next operation consists of the filling up of the holes engraved in the dial with a white compound. Only a small proportion of the dial markings will be luminised and it is essential that the remainder of the markings shall remain perfectly clear and easily distinguishable throughout the serviceable life of the instrument.

Luminising

If dials were luminised prior to assembly into the completed instrument, it is quite certain that in the handling or mechanical process required during assembly, a large proportion of the very valuable luminising material would be lost. Although it is convenient therefore to deal at this stage with the luminising of the dial, it must be borne in mind that the dial and the pointer together are luminised only when the instrument is entirely completed and ready for the screwing down of the bezel.

The luminous compound is supplied in 20-gramme bottles ; 1-gramme sealed tubes can however be obtained from the makers.

The parts to be luminised are first painted white, and it is necessary that the paint used must be perfectly free from lead. After the painting is completed and dried, and before luminising is begun, it is advisable that the parts to be luminised should not be touched with the finger, they must be kept perfectly free from the possibility of their being marked by grease or oil.

The luminous compound must first be prepared. It is mixed with a gum arabic solution, consisting of $1\frac{1}{3}$ oz. of the purest gum arabic in 1 pint of distilled water or lesser quantities of each in proportion. The solution is allowed to stand until all the gum arabic is dissolved ; it must

then be strained twice through thin muslin to remove all mistiness. If afterwards any misting or deposition develops, the solution should be thrown away and a fresh lot made up.

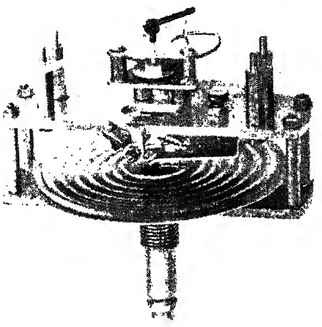
Fig. 7.—SHOWING THE DIAL OF A SMITH AIRSPEED INDICATOR FOR USE IN IRAN.

A small quantity of luminous compound is then put into a clean container, smaller than a watch glass. In view of the high cost of this material, an effort should be made to use up all the compound which has been mixed, as a special procedure is necessary should the mixture have to stand over for use at a later date. To the luminous compound in the watch glass is added the gum arabic solution, drop by drop, the mixture being stirred with a wooden rod until it reaches the consistency of cream, when no more gum arabic solution must be added. If the completed work has a glossy appearance it shows that too much gum arabic has been added; there is then a tendency for the luminising to come away whole; while too weak a solution or the addition of too much water leaves the luminising liable to flake away or to revert to powder.

If by chance more luminising compound has been mixed up than is needed at the moment, it can be softened later by the addition of alternate drops of plain distilled water and the gum arabic solution to which reference has previously been made. If water alone is used, the luminous compound will be too powdery after application.

When the compound is ready, the parts to be luminised are painted with a pale copal varnish. The varnish is applied with a brush and allowed to dry to the stage at which it is just sticky or "tacky." If the varnish gets too dry, the luminising may drop off, while if it is too wet, the luminising compound will mix with it and may therefore not be up to standard. When the varnished parts are sufficiently tacky, the luminising compound will be applied by means of a thin wooden rod.

On the instructions supplied by the maker it is stated that 1 gramme of luminous compound will cover about 25 sq. cm. of surface. Luminising as generally carried out is far thicker than this, as the depth of the engraving is 12 thousandths of an inch; after painting, the luminising is built up above the general level of the parts to a total thickness of about ·06 in. The amount of application is such that five to ten instruments can be luminised for each gramme of luminising compound.



[*Smith's Aircraft Instruments.*
Fig. 8.—CAPSULE OF AIRSPEED INDICATOR.

Pointers

Pointers are usually stamped out by the use of a specially built tool. This was the work of a single process at one time, when pointers were flat or nearly flat, being grooved down the middle to take the luminising compound. In recent years, pointers have been specified as being tubular except at the point, which is still hollowed out to receive the luminising compound.

Pivots and Bearings

Pivots, subjected only to a movement less than that through 360°, consist, in the inexpensive types of instrument, only of a step bearing cut or ground at the end of the hardened shaft. In more expensive types, a properly shaped and hardened pivot may be used in conjunction with a bearing of the type made and supplied by ball-bearing makers ; while in the most expensive instruments, used more in America than in this country, jewels such as sapphires may be used for the bearing, hollowed out to receive the conical end of the hardened shaft.

Where rotation at high speed is required by the principle of the instrument, ball bearings of one kind or another are used. Many gyros, including some of those used for automatic pilots, revolve upon a single ball set in a conical bearing ; others use ball bearings of the type familiar to any motor mechanic, except that they are much smaller.

Movements

Illustrations in previous figures show that the inside of most instruments contains some form of movement or gearing transmitting a motion of the operating unit to the pointer. One such movement is shown in Fig. 8, but all consist of one or more gear wheels, sometimes working in conjunction with a rack and pinion.

The wheels and racks are usually stampings from brass plates, twenty or more stampings are bolted together and the teeth formed by means of gang milling. Each separate wheel or quadrant then requires polishing up to remove rough edges.

Diaphragms

At one time, diaphragms were made of oiled silk; in recent years the

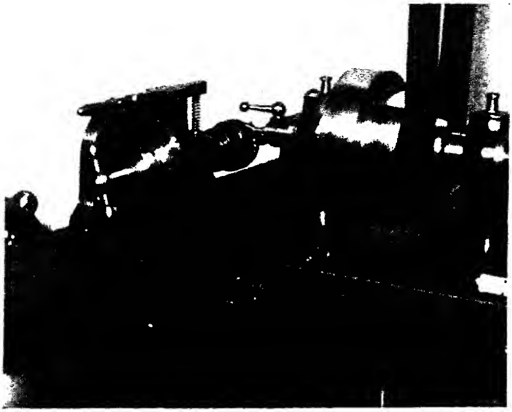


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Fig. 9.—JIG USED IN THE PRODUCTION OF GYROSCOPE WHEEL.

technique of producing diaphragms from flexible metal has advanced to the stage at which the latter are coming into almost universal use. The term diaphragm is usually applied to a single sheet of metal, most frequently nickel silver, corrugated in concentric rings. The rim is fixed in various ways to the case of the instrument so as to provide on either side of the diaphragm an airtight chamber; the movement of the centre of the diaphragm is transmitted to the pointer either by a connecting link soldered to the centre or by the pressure of a light shaft not fastened to the diaphragm but kept in touch with it by a spring.

The diaphragm blank is stamped out and the corrugations are then stamped upon it, usually with the nickel-silver blank resting upon a rubber bed.

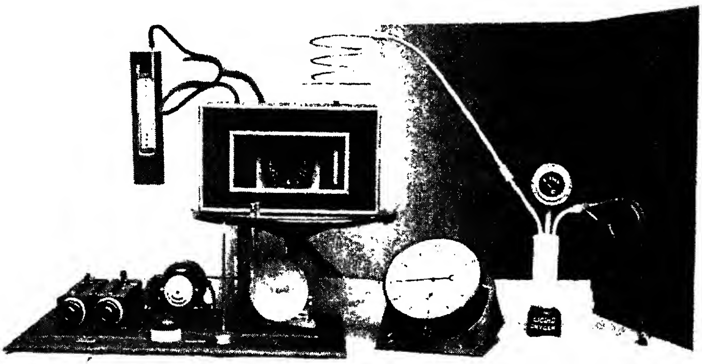

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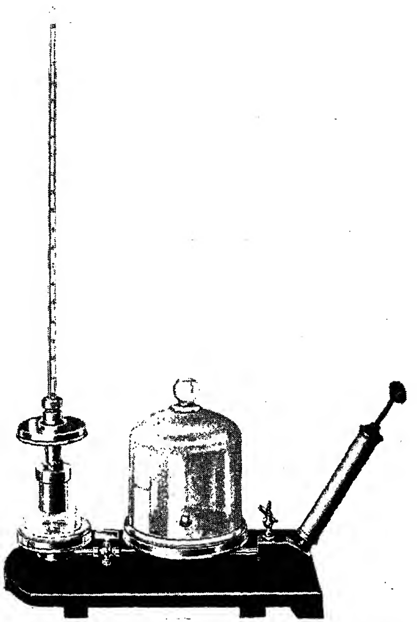
Fig. 10.—LOW TEMPERATURE TEST OF TURN INDICATOR.



[*Smith's Aircraft Instruments.*

Fig. 11.—ALTIMETER TESTING APPARATUS.

Capsules

A capsule consists of two diaphragms soldered together at the edges in such a way as to form an airtight box. This box may be partly or almost entirely exhausted or may be connected as in the airspeed indicator to a source of pressure different from that to which the outside of the box is subjected. In either case, pressure variations will result in movements or breathing of the sides of the capsule; this motion is transmitted through suitable multiplying gears to the pointer, as in Fig. 8.

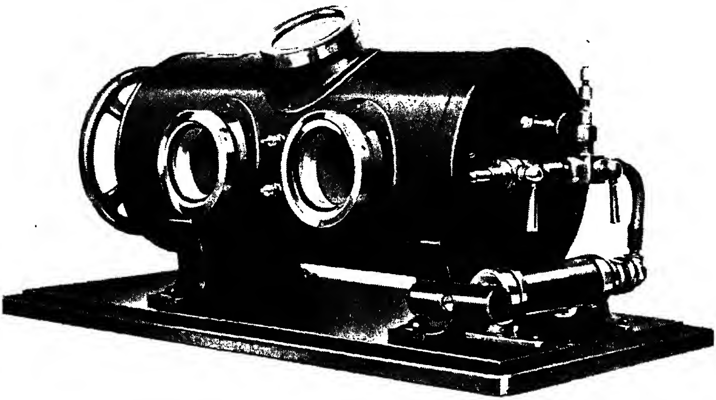
Sylphon tubes used in compasses, and also for the control of automatic boost, bear a resemblance to capsules, but the corrugations run round the circumference instead of outwards from the centre of a circle. Sylphons are made from thin gauges of metal by spinning.

Bourdon Tubes

The Bourdon tubes used in many pressure gauges are drawn, usually from copper, cut to length and rolled into shape after having been filled with sand to prevent flattening; the end is then soldered. The manufacture of steel Bourdons intended for use with thermometers is dealt with elsewhere in this volume.

Gyroscopes

Gyroscopes are used in turn indicators, directional gyros, artificial horizons and automatic pilots of various types. The wheels themselves may be cut from a circular bar of brass or bronze, the blanks are then turned to size on capstan lathes, operations such as the recessing of the



[*Smith's Aircraft Instruments.*

Fig. 12.—PORTABLE ALTIMETER CALIBRATOR.

This instrument can be used with a precision altimeter as standard, or with a portable mercury column.

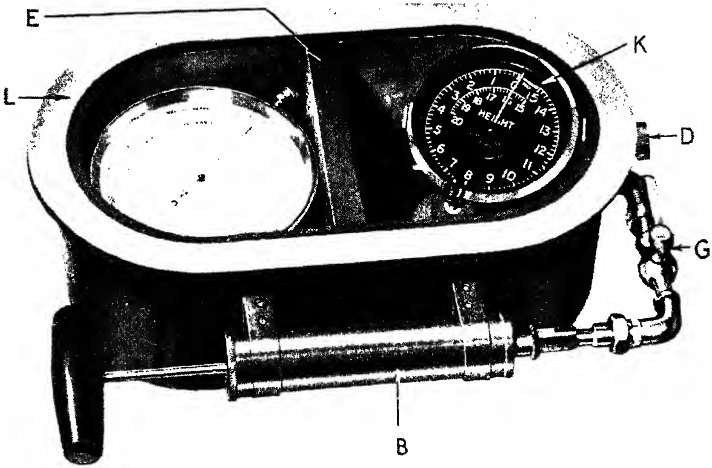


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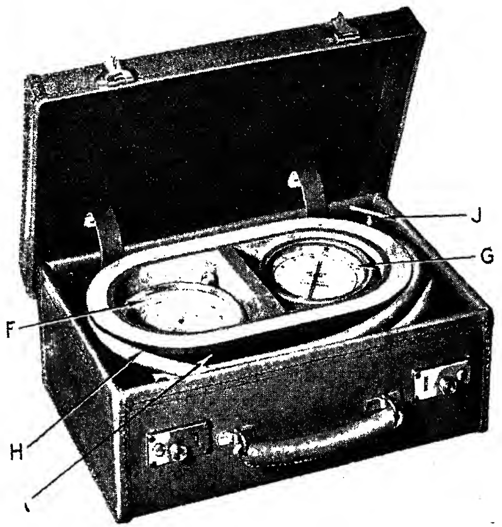
Fig. 13.—LIGHT PORTABLE APPARATUS FOR TESTING ALTIMETERS AND AIRSPEED INDICATORS.



[*Smith's Aircraft Instruments.*

4.—PORTABLE TESTING APPARATUS, AS FIG. 13, PACKED FOR TRANSIT.

sides being carried out at the same time. The buckets upon which the air jet impinges are then milled in the circumference. If the buckets are of a simple form this can be carried out in one operation by means of a dividing head controlling the rise and fall of the milling cutter and another adjusting correctly each forward movement of the blank. In complex buckets two tools and two operations may be required for each or at the least a re-entry at a different angle of the tool first used. The jig is shown in Fig. 9.

The wheels are then fitted with spindles, mounted in their gimbals complete with bearings and pivots, run up to speed by means of air pressure jets and balanced both statically and dynamically. They are then ready for assembly into the instrument.

Testing and Calibration of Turn Indicators

Turn indicators testing is dealt with on p. 319 of Vol. III.

The testing of all instruments will vary according to the instruments themselves, but it is usual for a proportion of all types to be tested upon a vibrating table and under conditions of heat and cold corresponding to the maximum range required. The extreme temperature may be as far apart as $-60°$ C. and $+60°$ C.; the rig for applying this cold test to turn indicators is shown in Fig. 10.

Vibration tests are carried out with the aid of the tester illustrated and described on p. 324 of Vol. III.

Testing of Altimeters

Altimeters may be tested either by a standard mercury column or

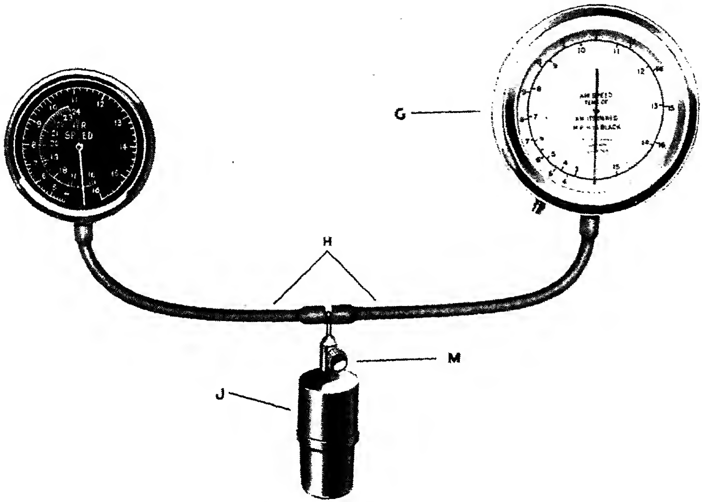


Fig. 15.—CONNECTIONS WHEN USING PORTABLE CALIBRATOR (FIGS. 13 AND 14) FOR TESTING AIRSPEED INDICATORS.

against a standard instrument. Fig. 11 shows the mercury column testing apparatus, used in the laboratories of instrument makers or those in the engineering buildings of large aerodromes.

It consists of a standard mercury column, a metal base surmounted by a glass bell-jar and a vacuum pump. These are connected by a common pipe line with taps for isolating the barometer and for controlling the re-admission of air.

Sent out with every instrument is a chart showing the height in thousands of feet corresponding to inches of mercury. It is therefore only necessary to place the altimeter under the bell-jar and work the vacuum pump, watching both the mercury column and the altimeter under test to see that the reading given is correct.

The method of use is as follows :—

(i.) Place altimeter under bell-jar (vacuum chamber).

(ii.) Open tap between jar and mercury column.

(iii.) Work vacuum pump, drawing the mercury down to a given figure (see chart for equivalent of inches of mercury to thousands of feet).

(iv.) After reading the instrument over the required range "Up-reading," open tap between jar and pump, gently closing when mercury reaches the required figure for each "Back-reading."

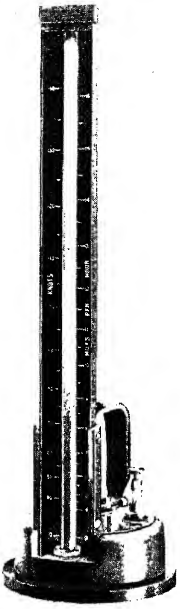


Fig. 16.—SMITH PORTABLE AIRSPEED CALIBRATOR USES A COLUMN OF DISTILLED WATER.

Fig. 12 illustrates a more suitable pattern for use either on ships or aerodromes abroad where a standard mercury column might be inconvenient.

The calibrator consists of a cylindrical metal chamber, at one end of which are the control taps and at the other a circular door with an expanding gasket. The cylinder is furnished with three inspection windows, and is mounted on a wooden base, which also carries an exhaust pump.

A precision altimeter or other standard instrument is placed in the calibrator together with the instrument to be checked; a whole range of reduced pressures could well be provided by means of the exhaust pump.

Another pattern, illustrated in Figs. 13 and 14, can be used also for testing airspeed indicators.

The apparatus consists of an oval aluminium casting A, open at the top, which when covered with a sheet of glass (omitted from the illustration) forms a vacuum chamber suitable for testing altimeters. The exhausting pump B, Fig. 14, is fitted with two valves, is clamped to the side of the casting and is of solid brass. A cock C is fitted between the pump and the casting in order to isolate the receiver and to prevent stray leakages through the pump. An air-leak valve D is fitted to the side of the casting to allow the air to re-enter slowly.

If desired, the casting can be fitted with a cock and rubber connection for use in conjunction with a mercury barometer.

The casting is lined throughout with sponge rubber E to prevent damage to the sub-standard altimeter F and the sub-standard airspeed indicator G, which are supplied with the set.

To test an altimeter, remove the vacuum chamber from the carrying case and substitute the altimeter under test K for the sub-standard airspeed indicator, which is normally carried for convenience in the vacuum chamber. An airtight joint is then made between the glass and the flange L on the casting, by smearing the flange with a little of the special grease which is supplied, the glass then being pressed home.

The sub-standard altimeter is supplied with two scales, $-$ 1,000 ft. to $+$ 10,000 ft., one scale calibrated according to I.C.A.N. law and the other according to isothermal law.

When exhausting the chamber for "up-readings" the release valve should be closed and should only be used to control the use of the vacuum.

A test report giving the exact errors of the sub-standard altimeter is supplied with the set.

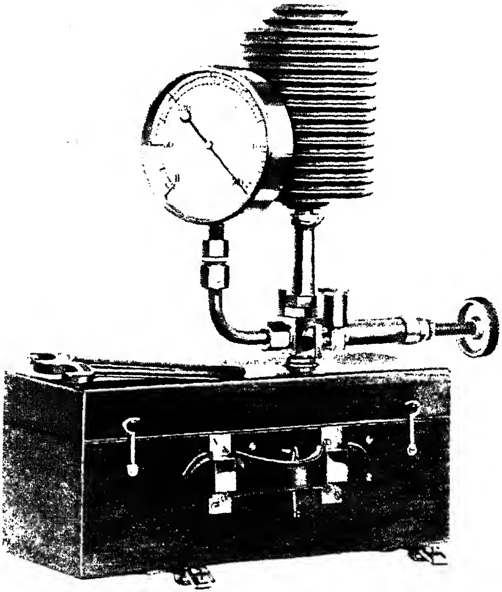


Fig. 17.—SMITH PORTABLE CALIBRATOR FOR PRESSURE GAUGES
Showing the apparatus fully erected.

Testing of Airspeed Indicators

For testing airspeed indicators, the metal pump should be connected, by means of the rubber tubing provided, to (*a*) the pressure nipple on the sub-standard airspeed indicator and to (*b*) the pressure nipple of the airspeed indicator to be tested. This can be done, if necessary, without removing the airspeed indicator to be tested from its position on the instrument panel (see Fig. 15).

By means of the pump, the pressure inside the two instruments can be raised by quite small stages. A release valve M is provided for controlling the release of the pressure during "down-readings."

In addition to thus testing an airspeed indicator for accuracy, this method will reveal the presence of any leak in the instrument under test.

A less expensive instrument for the testing of airspeed indicators is illustrated in Fig. 16; the method of use is as follows:—

(i.) Fill container with distilled water until approximately $\frac{1}{8}$ in. is showing in the glass tube.
(ii.) Adjust cursor on glass tube in line with meniscus of water.
(iii.) Adjust dial of calibrator until zero is in line with cursor.
(iv.) Connect instrument to the nipple without the regulator.
(v.) Adjust cursor to reading required, then apply air pressure

through inlet nipple, closing the regulator when the water reaches the required reading.

(vi.) To take a down- or back-reading, disconnect pressure appliance and open regulator valve.

Testing of Pressure Gauges

Pressure gauges should be calibrated by means of the apparatus shown fully erected in Fig. 17.

The apparatus consists of a dead-weight piston and cylinder combined with a hand-screw press pump, by means of which fluid pressure is applied to the piston of the dead-weight portion and to the gauge under test. An oil container fitted with shut-off cock is built on to the base of the dead-weight cylinder. The connection to the gauge under test is by means of a right-angled bend, one end of which is coupled to the cylinder base, the other end to a screwed adaptor to fit the gauge shank.

The method of use of this calibrator is as follows :—

Remove the knurled screw from the brass socket in the lid of the box and screw the tester in position. Couple up the right-angled connecting pipe and fix the gauge to be tested by means of the appropriate adaptor.

Open the cock at the bottom of the oil container and screw the pump plunger right in.

Fill the oil container with thin mineral oil and screw out slowly the pump plunger. This draws the oil into the pump barrel.

Shut the cock of the oil container.

Place weights equivalent to the desired pressure on the dead-weight piston.

Open the cock at the base of the dead-weight cylinder and apply pressure to the system by screwing in the pump plunger, at the same time revolving the weights by hand until the dead-weight piston rises off its seat. A balance of pressure is now obtained. In the event of one stroke of the pump plunger being insufficient to produce the desired pressure, shut off the dead-weight cylinder and gauge by means of the cock and refill the pump barrel with oil from the container.

When taking readings, the weights must be kept rotating and the dead-weight piston must be lifted from its seat.

Acknowledgments

Acknowledgments are due to the firms whose names appear beneath the illustrations of their products ; and in addition, to Smith's Aircraft Instruments for the method of using the various items of their testing equipment.

THE "GIPSY MAJOR" ENGINE

CONSTRUCTION AND ASSEMBLY

By A. J. Brant

Service Manager, de Havilland Aircraft Co. Ltd.

THE Gipsy Major is a four-cylinder, inverted, air-cooled, direct drive engine, the leading particulars of which will be found on p. 2, Vol. III.

Cylinders

The cylinder barrels are machined all over from carbon steel forgings, Specification 570. Special attention has been directed to the graduation of wall thickness and depth of finning in order that distortion may be avoided and an even cooling effect obtained. The ends of the barrels project deeply into the interior of the crankcase and so provide an ample capacity for oil drainage without any danger of flooding the pistons. An oil-tight joint is assured by the use of a Dermatine ring which is trapped in a recess between the cylinder flange and the crankcase face. The exposed surfaces of the cylinders are specially treated against corrosion.

Cylinder Heads

The cylinder heads are detachable, each being held to the barrel by four long, high-tensile studs which extend from the crankcase. A gas-tight joint is maintained between the head and barrel by the interposition of a copper and asbestos washer located in a recess in the cylinder head. The heads themselves are cast in *aluminium bronze* (Specification D.T.D.135)—a material of great strength and toughness on which the valves can seat directly. One inlet and one exhaust valve are provided for each cylinder. The sparking plugs are screwed, one on either side, directly into the material of the head, no adaptors being necessary.

The finning has been carefully arranged so that, with the adequate area provided, effective cooling is a straightforward matter on any aeroplane. As the valve ports and manifolds are arranged on the starboard side, the slipstream from the airscrew (L.H. Tractor) carries any fumes away from the cockpits and materially reduces the audible noise.

Pistons

These are of the slipper type—cast in heat-treated aluminium alloy to D.T.D. Specification 131. The piston is so designed that the thrust from the crown is taken direct to the gudgeon pin bosses and is

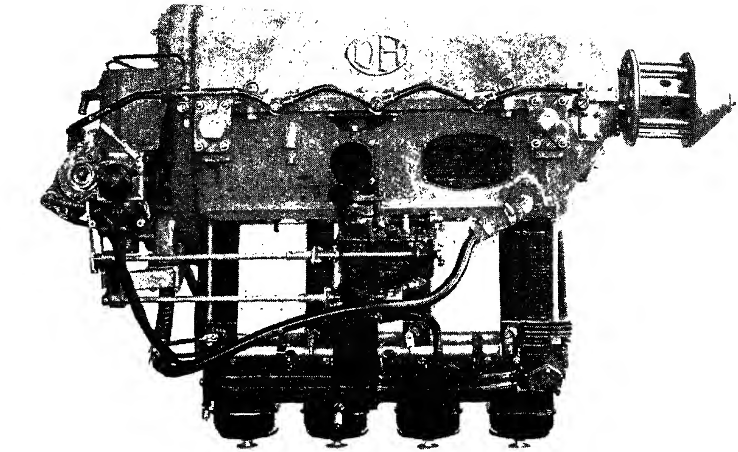


Fig. 1.—Starboard view of "gipsy major" engine.

not transmitted *viâ* the skirt. Fully floating gudgeon pins have been adopted and are located at each end by external circlips and washers. Three piston rings are fitted below the gudgeon pin on each piston. The ring nearest the gudgeon pin is of the scraper type and contributes to the low oil consumption of this engine.

Connecting Rods

The connecting rods are machined from forgings of D.T.D. 130 alloy. They are of robust design. The big end is exceptionally rigid, being clamped by *four* high tensile bolts. A bronze shell, lined with white metal, constitutes the big-end bearing.

Crankshaft

This is machined all over from a nickel-chromium alloy steel forging and is carefully balanced. It is carried in five plain bearings, while a ball journal bearing is provided near the front end to locate the shaft and take thrust in either direction from the airscrew. The ample support thus provided and the rigid construction employed ensure perfect alignment at all times and make for very smooth running. Journals and pins are drilled both for lightness and lubrication, all main bearings being fed continuously with oil under pressure.

Airscrew Boss

This is fitted on a tapered extension of the crankshaft and is provided

with eight bolts and a quickly detachable spinner. The main boss need not be disturbed on its taper for airscrew changing: this operation may be quickly performed by withdrawing the airscrew together with the flanged sleeve which is an easy fit over the boss proper.

Crankcase and Top Cover

The crankcase is light alloy to Specification L.5. The top cover is light alloy to Specification D.T.D. 59 early engines; D.T.D. 136 later engines.

The crankcase and top cover are bolted together in the horizontal plane of the crankshaft centre line. The whole forms a very rigid assembly, as the crankcase has considerable depth and is well webbed internally. Each intermediate bearing is supported by a stiff cross-member extending right across the crankcase. The main bearing shells are retained by separate caps which, being readily accessible by removal of the top cover, facilitate assembly, inspection and overhaul. Appropriate facings are provided on the crankcase for bearer feet, breather, fuel pumps, oil drain pipe and lifting attachments.

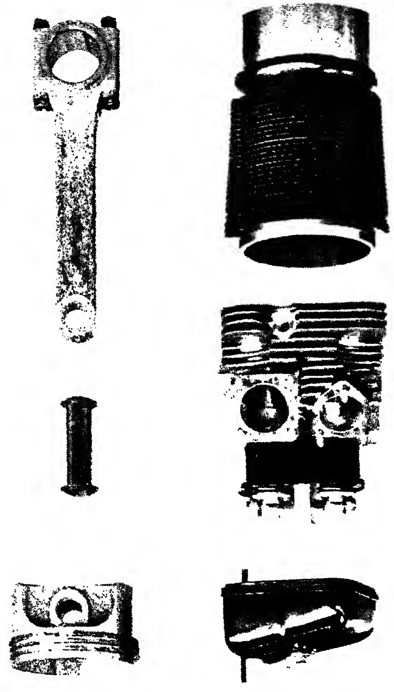


Fig. 2.—CYLINDER, CYLINDER HEAD AND VALVE GEAR, PISTON AND GUDGEON PIN, AND CONNECTING ROD.

Camshaft and Valve Operation

The camshaft is supported by five plain bearings on the port side of the crankcase and operates directly on hardened steel tappets. The motion is transmitted to the valves by tubular push rods and steel rockers. The push rods on early engines are duralumin and later steel.

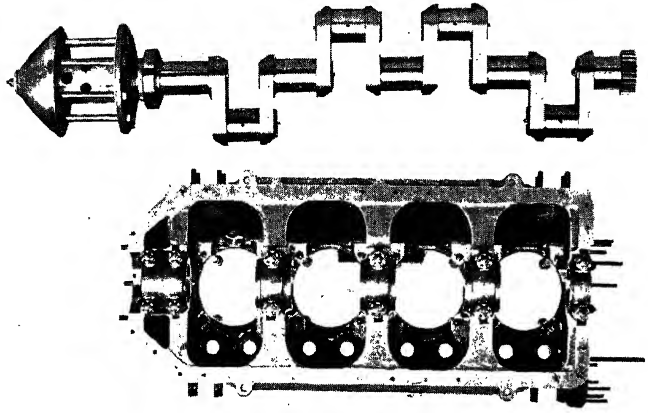


Fig. 3.—CRANKCASE AND CRANKSHAFT.

The bushed rockers oscillate on a hardened spindle which is attached to the cylinder head by a stout steel bracket. A simple means of adjusting the valve clearance is provided by a movable screw with locknut accessibly mounted on the push rod end of the valve rocker. All striking parts of the valve gear are hardened and are readily replaceable. A hardened thimble is fitted on the end of each valve stem. The whole of the gear is totally enclosed and is lubricated by splash from the rockers dipping in an oil bath provided in the valve casing covers.

Owing to the exclusion of dust and to the excellent lubrication provided, wear of the moving parts is very small indeed even after prolonged running.

Timing Gears and Magnetos

Timing gears are housed in a separate cover built on to the rear end of the crankcase. The camshaft is driven by spur gears from the crankshaft. An intermediate wheel in this train incorporates a spiral gear which drives the magneto cross-shaft.

The two magnetos are mounted on platforms, one at each end of this cross-shaft, to which they are connected by Simm's flexible vernier couplings.

An impulse starter is incorporated on the starboard magneto. This device ensures that the magneto delivers a very strong spark at slow revolutions and so facilitates starting. As the distributors and contact breakers point outwards, they are particularly accessible for inspection or adjustment.

Fig. 4.—OUTLET OF CRANKCASE BREATHER SHOULD BE FREE OF SLIP STEAM SUCTION OR PRESSURE.

The spark advance levers are so interconnected with the throttle that the point of ignition is automatically advanced or retarded to suit the varying factors of speed and load.

Induction System

Mixture is supplied by a Claudel Hobson A.I. 48 Down-draught carburetter situated on the starboard side of the engine. On early engines a pressed steel induction manifold is fitted, and the riser portion from the manifold proper to the carburetter flange is jacketed and heated by exhaust gases led from the exhaust manifold. Bosses can be provided on the induction manifold for connection to a doper system which, though normally unnecessary, may be used if desired.

On later productions an internal air intake was introduced to eliminate the possibility of engine failure due to ice formation in the carburetter choke and on the throttle butterfly.

In order to conform with the airworthiness requirements, a flame trap, developed by Messrs. Amal, is fitted to the internal air intake facing and close to the crankcase to obtain warmed air. An external air intake is also provided and a flap control is arranged to bring either the hot or cold air intakes into operation.

Cowling

Aeroplane constructors are strongly advised to use the airscoop which is supplied with the engine. In most cases this will be found to fit in with the general outline required. This part has been carefully tested, and will be found to give satisfactory results with very little or no experimental work on aeroplanes with performance as indicated in a later paragraph.

Should the airscoop, etc., be made up entirely by the constructor, the following points should be noted :—

To obtain the best cooling effect, every endeavour should be made to keep the pressure of air in the scoop as high as possible. This can be

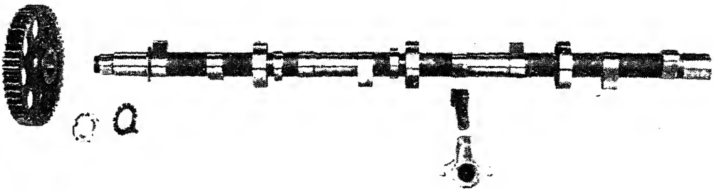


Fig. 5.—CAMSHAFT, GEAR AND TAPPET.

attained by keeping the frontal area of the scoop up to—at least—the same area as the scoop supplied, and by cutting down the leaks to a minimum. Studs are provided in the crankcase near the tappet facings and should be used for the upper fixing of the scoop.

The lower fixing of the scoop is provided for by the hinge attached to the four small pieces of cowling attached to the valve gear casings.

It is important that the lead in from the nose cowl to the airscoop should be made the best possible fit, consistent with sufficient clearance to allow the engine to oscillate in the rubber mounting, otherwise the air which flows in through the nose cowl may not enter the airscoop and flow inside the cowling. This is a bad defect in that it puts up the pressure in the cowling, retards the easy exit of air from the cylinders, and necessitates larger outlet holes in the cowling than are needed.

An easy exit for the air from inside the cowling must be provided, and can best be arranged by bulging the cowling where it overlaps the fuselage, leaving a slot facing rearwards between cowling and fuselage.

The top cover and crankcase should be well ventilated and a small amount of ventilation should be provided round valve gear casings and covers. The amount of cooling provided on the crankcase and top cover is important, as it reduces the temperature of the oil in circulation and thus affects the design of the tank as an oil cooler.

With any new design of scoop or cowling it is advisable to check cylinder head and oil temperature in flight. The head temperature can best be checked by attaching thermo-couples under the sparking plugs on the side of the engine remote from the airscoop. The maximum permissible temperature of any cylinder during the steepest climb at full throttle is 280° C. The more desirable maximum to aim at is 250° C. If this latter temperature is not exceeded under conditions mentioned above, the temperature for other conditions of flight will be satisfactory.

The maximum oil temperature recorded on a thermometer fitted in the inlet pipe to the engine should not exceed 90° C. This temperature should be between 70° C. and 90° C., and although no trouble need be expected if the engine should be run with the temperature at 90° C.,

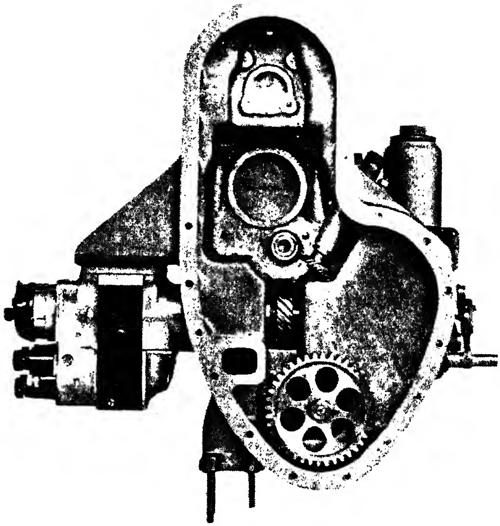


Fig. 6.—INTERIOR OF TIMING GEAR COVER.

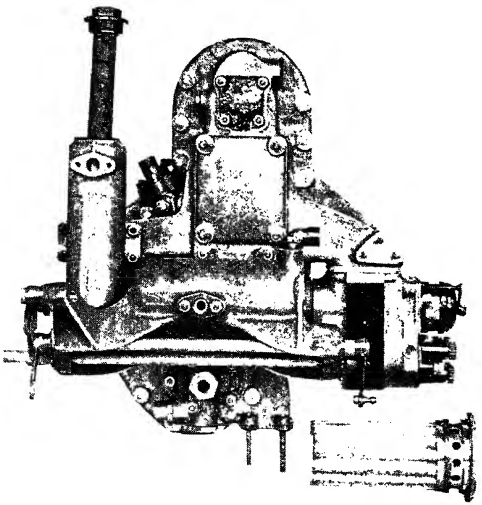


Fig. 7.—EXTERIOR OF TIMING GEAR COVER.

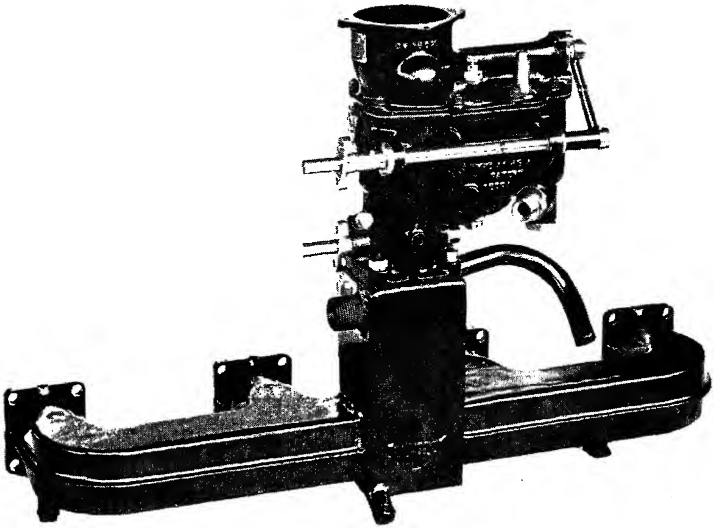


Fig. 8.—INDUCTION PIPE AND CARBURETTER.

every endeavour should be made to keep the temperature at the low end of this range.

We give below the air inlet and outlet areas for an average installation. These figures are suitable for an aeroplane with a maximum speed of 120–130 m.p.h. and the inlet areas should be increased should the maximum speed be below these figures.

Inlet Areas

	s
Area of scoop	58
,, vertical slot in nose opposite centre of front cylinder	4
,, hole in nose cowl opposite exhaust manifold and branches	6
,, gap between edge of spinner on airscrew and hole in nose cowl	8
Total	76

Outlet Areas

	sq. in.
Total area .	90

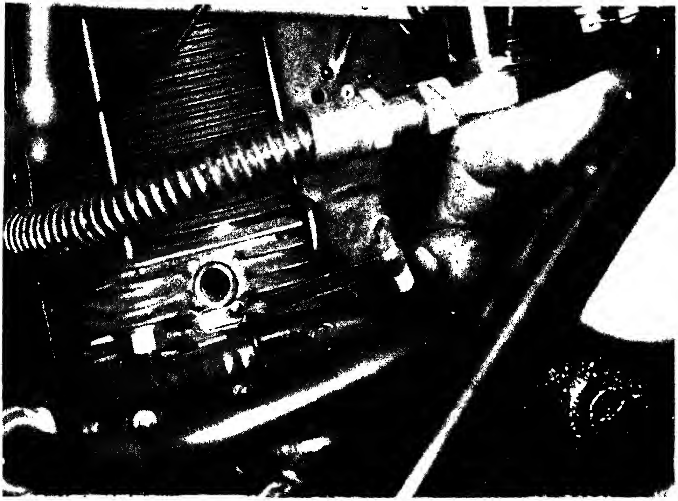


Fig. 9.—The face for the attachment of blind revel type thermo-couple.

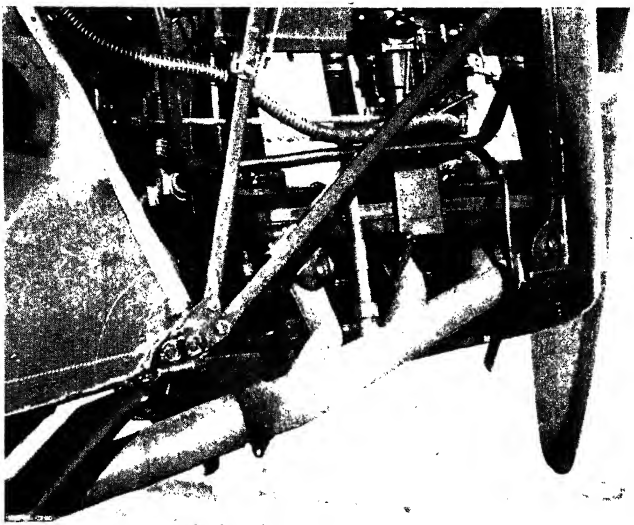


Fig 10.—A typical exhaust manifold.

About 30 per cent. of this area should be round the exhaust manifold or branches. The remainder should be provided as far to the rear of the engine bay as possible.

Induction System

In the case of engines fitted with the pressed steel type induction manifold, the heater muff must be correctly connected to the exhaust system.

At the rear of the heater muff, a $\frac{5}{8}$-in. B.S.F. union is fitted, and engines are supplied with a nut and nipple to suit. A length of $\frac{5}{8}$-in. o/d $\times$ 20 S.W.G. steel tube must be fitted up between the above-mentioned union, and a similar union must be welded in a suitable position on the exhaust manifold, approximately on the centre-line of number four cylinder.

When engines are fitted with an exhaust "lead-away" pipe, this connection to the exhaust manifold can be flush with the inside, but, if there is no exhaust "lead-away" pipe, an elbow will have to be incorporated, protruding inside the manifold as far as the centre-line, and with its open end facing into the flow of exhaust gases.

In the afore-mentioned length of tube, some provision must be made for expansion and vibration, and it is suggested that either a sliding steel sleeve joint or else a short length of flexible metallic tubing is incorporated.

The hot exhaust gases are thus collected from the exhaust manifold, carried *viâ* the steel tube to the heater muff where they circulate freely and so slightly warm the mixture, and are then dispelled out of the short length of tube which is fitted at the front of the heater muff. A length of steel tube must be slipped over this outlet tube, and held into position by means of a suitable clip welded to the tube, and bolted to the bracket on the induction manifold provided for the purpose. The outlet tube must then drop downwards and project below the cowling approximately 1 in., where it must be cut off at an angle of 45 degrees in order that the forward speed of the aeroplane tends to create a vacuum in the tube, so assisting the gases to escape.

Fuel Systems (all types)

The fuel pipes which are attached entirely to the structure of the aeroplane can be run in copper tubing and, unless there is a considerable relative movement between the parts of the structure, no flexible joints are necessary. The joints of the pipe can be made by A.M. type metal coupling or brazed nipples and union nuts. Where the fuel pipe crosses from aeroplane structure to engine a flexible pipe such as "Petroflex" should be used.

Where rigid fuel pipes are used, these should be well supported so that no vibration is set up caused by their own weight.

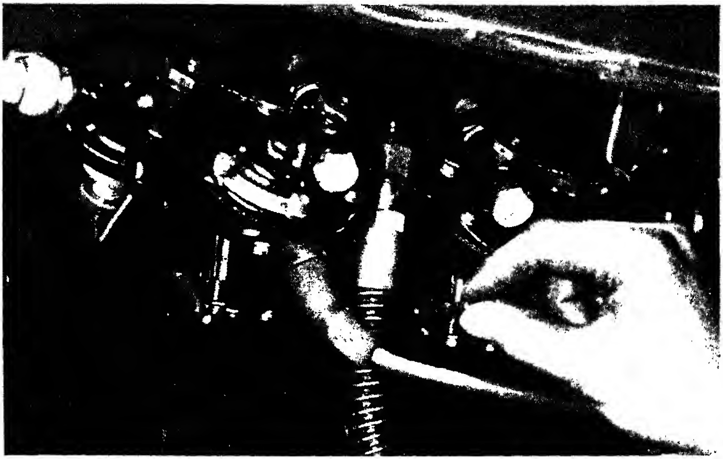


Fig. 11.—THE DE HAVILLAND A.C. FUEL PUMP FITTED TO GIPSY MAJOR ENGINE.

A fuel filter with ample sump capacity should be fitted in the pipe line in an accessible position on the aeroplane.

Fuel Systems (Gravity)

All pipes, filters and cocks should have at least $\frac{5}{16}$-in. clear bore. Piping should be arranged with a steady fall from the tank to the carburetter, and vertical bends or a close approach to the exhaust pipe or manifold avoided, as these conditions tend to cause air or gas locks in the fuel system.

The head of fuel on the carburetter should be at least 1 ft. with the aeroplane at climbing angle. The flow to the carburetter should be at least 18 gallons per hour taken with the aeroplane at ground angle.

Fuel Systems (Dual Pumps)

With this system the pumps deliver their fuel directly to the carburetter and no reserve supply is necessary. When the engine is supplied with dual pumps the necessary piping to connect these to the carburetter is fitted to the engine by the manufacturers. It will only be necessary to connect up the suction side of the pumps to the supply pipe from the tanks in the aeroplane. On very early engines when A.C. Sphinx were fitted it was necessary to arrange a doping pump to enable the carburetter to be filled with fuel for starting. For this purpose a simple form of plunger pump was fitted and connected up by means of a single pipe to a special valve cap in one of the A.C. pumps. With these pumps it was

necessary to make some provision to allow a check to be made to test the functioning of each pump separately. This can be arranged by providing a duplex cock in the engine bay from which run separate pipes to the suction side of each fuel pump. These should be normally locked in open position and only used to check the working of each pump when running up engines on ground. These cocks should not be used as a means of control as it is very undesirable to run for long periods with the suction side of a fuel

Fig. 12.—THE FUEL FILTER.

pump turned off. The early D.H. 84 Dragon aeroplanes were fitted up in this way.

As previously explained, later engines are fitted with D.H.A.C. fuel pumps, and in this case the above doping and checking arrangement is not required as these pumps are provided with an external lever for hand operating the diaphragms of the pumps for priming the carburetter and checking purposes.

Special precautions are necessary when fitting up the suction

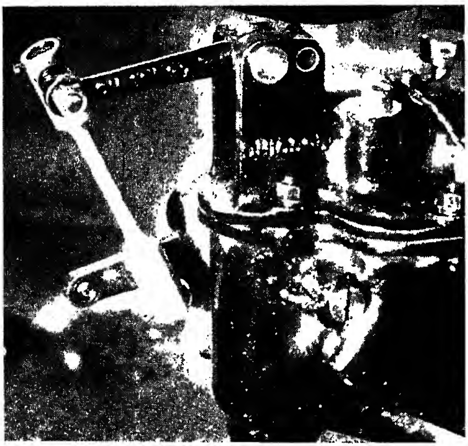


Fig. 13.—MIXTURE CONTROL VALVE, PLUNGER PUSH AND PULL OPERATED TYPE ON A.I. 48 CARBURETTER SUBSEQUENT TO TYPE "E".

piping on installations using fuel pumps, as air leaks which are very difficult to detect are a possible cause of engine failure.

Fuel Pumps

Facings are provided on the crankcase to allow for the fitting of the dual fuel pumps, in which case a camshaft with the necessary additional cams for operating the pumps is fitted. This type of camshaft is now standard, but on very early engines was only fitted when specially ordered. Blanking plates are fitted over the facings when pumps are not required.

Fitting of Diaphragm Springs

Owing to differences in the amount of suction lift or head that this type of pump has to cater for on different installations it has been found necessary to be able to fit either of two types of diaphragm springs. The weaker springs, coloured green, should be fitted for an installation where there is pressure on the suction side of the pump and for small suction lifts.

The stronger spring, coloured blue, should be fitted for any installation with 6 in. or more suction lift or where restriction is put on the suction side of the pump by lengthy or small bore piping. This diaphragm spring of whichever type is found necessary is fitted under the spindle which operates the diaphragm. The copper-coloured spring which is fitted under a projection of the rocker remains unaltered in either case.

Magneto Wiring

The earthing terminals on the contact-breaker covers should be connected up to a suitable duplex switch, so that the magnetos can be earthed separately for test purposes. The earth connection on the switch should be wired direct to some part of the engine. The switches should be identified by suitable labels, to show whether connected to port or starboard magnetos. The wiring, etc., should be carefully carried out as the safety of the people working on the engine or swinging air-screws depends on the switches working correctly.

Oil System

A nut and nipple is provided at the rear end of the oil gallery (on early engines) and on pressure filter casing (on later engines) for the attachment of a pipe leading to the pressure gauge. A fuel-resisting rubber connection should be provided in this pipe as close as possible to the engine end, and the pipe should then be clipped to the airframe structure. Coils to take up vibration in this pipe are not necessary, and generally are troublesome, due to vibration caused by their own weight.

The oil return pipes are supplied with the engine and terminate in a single connection suitable for 1 in. inside diameter fuel-resisting rubber hose.

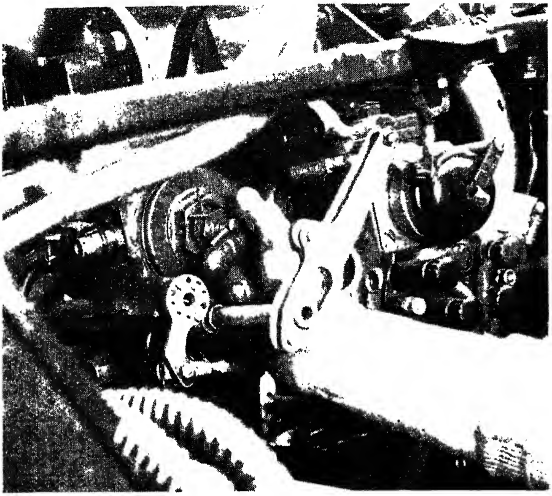


Fig. 14.—THE AUTO-KLEAN FILTER.

The oil tank in the case of gravity return systems should be sufficiently low to allow a good fall from the front oil connection on crankcase to the top surface of the oil in the tank when the aeroplane is gliding with engine off. The oil return piping should not be smaller than 1 in. outside diameter, and should the pipe be of any considerable length, a larger size could be used with advantage.

The suction pipe, if of steel or copper, should have two fuel-resisting rubber joints in its length, one of these should be fitted on the elbow of the suction filter and the other where the pipe joins the tank. If the suction pipe is attached to the airframe structure there should be two joints in the pipe between the point of attachment and the suction filter elbow. Before fitting fuel-resisting rubber joints the copper or steel tubing should be beaded and should be free from any sharp edges, etc., which will tend to damage rubber connections internally when these are being fitted. A flexible pipe such as "Superflexit" can be used, making a neater and more satisfactory job.

A pressure gauge reading 0–60 or 0–100 lbs. per square inch should be used. With any gauge reading higher than this the scale will be rather close.

A chamber can be provided in the oil inlet pipe to engine for a thermometer. As outside temperature effects on the end of the bulb, union and capillary affect the accuracy of the readings, the following precautions should be taken. The end of bulb and union nut should be lagged with asbestos cord. The amount of capillary in the engine bay or exposed to the outside air should be as small as possible. If the capillary has to be coiled to lose length, this coiling should be carried out in the cabin or the cockpit of the aeroplane. The capillary should not run closely to the exhaust manifold or take-away pipe at any point.

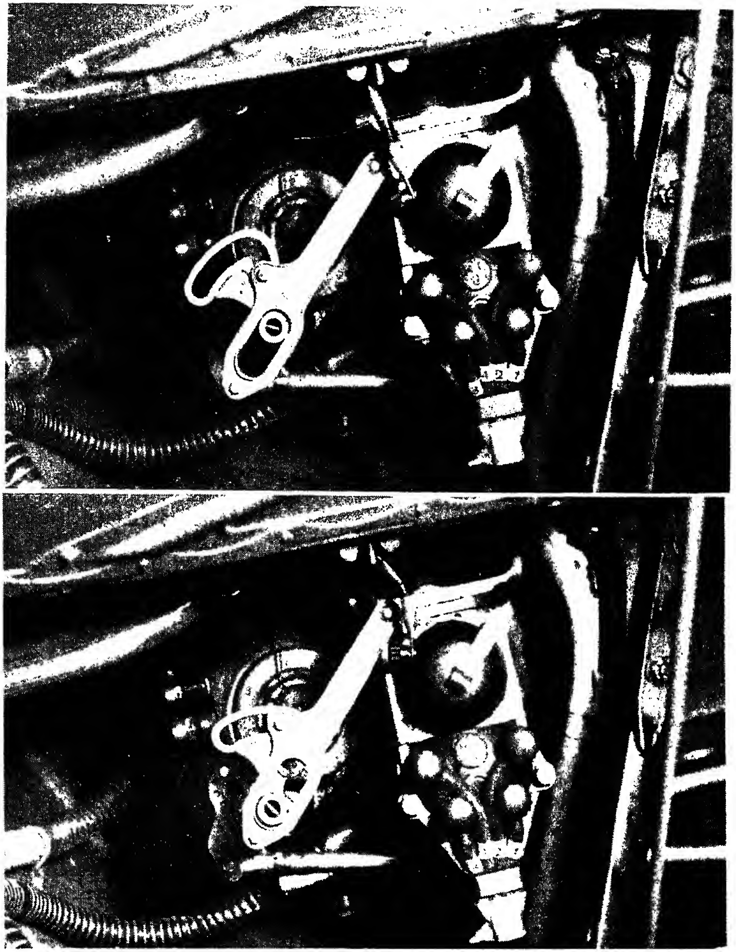


Fig. 15.—SHOWING AUTOMATIC ADVANCE AND RETARD OF MAGNETO WITH THROTTLE.

The throttle and magneto controls are interconnected on the engine in such a way that the magnetos are running in the fully advanced position under all cruising conditions, and are retarded for slow running. *Top,* Fully retarded, slow running position. *Bottom,* Normal running or cruising position.

Controls

Engine control levers in the aeroplane should be connected up to levers provided on the port side of the engine cross-shafts. It is important that the controls in the aeroplane give slightly more than sufficient movement in order to give full travel to the controls on the engine. This will ensure control levers being brought positively up against the stops on the carburetter.

The throttle and magneto controls are interconnected on the engine in such a way that the magnetos are running in the fully advanced position under all cruising conditions and are retarded for slow running.

Tachometer Drive Attachments

Attachment for any of the following types of tachometer drives can be supplied on the engine :—

Engine speed (single).
Engine speed (dual).
$\frac{1}{2}$ Engine speed (single).
$\frac{1}{2}$ Engine speed (dual).

To obtain steady readings on the tachometers the run of the flexible drives should be as free from bends of small radius as possible. This will also prolong the life of the flexible shaft as bends impose a considerable amount of extra stress on this part.

Airscrew Boss

A flanged type airscrew boss is provided on the crankshaft suitable for mounting a wooden airscrew of normal construction on a Fairy Reed fixed pitch metal airscrew.

Exhaust System

An exhaust manifold should be fitted and provision made for the induction heater pipe where the pressed steel induction manifold is fitted. An extension pipe from the manifold is desirable to increase comfort by the reducing of noise. This extension should be provided with a sleeve to fit over the outlet from the manifold. The extension pipe should be located by clips on the airframe and expansion should be catered for by allowing sufficient clearance between the ends of the pipe inside the sleeve.

GIPSY SIX" SERIES I AERO ENGINE

CONSTRUCTION AND ASSEMBLY

By A. J. Brant,
Service Manager, de Havilland Aircraft Co. Ltd.

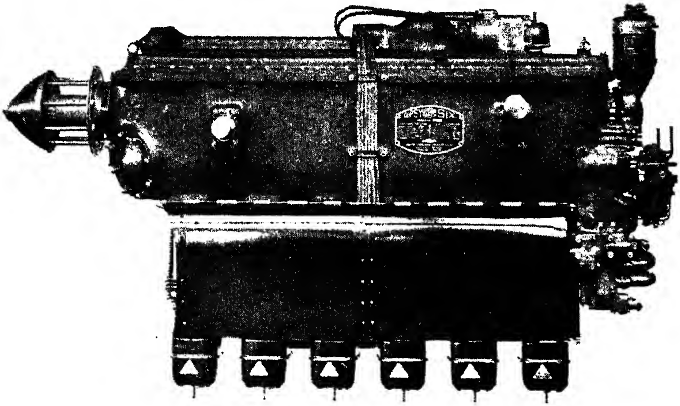


Fig. 1.—"Gipsy six" series i aero engine.
Port view.

THE Gipsy Six Series I engine is the development of the range of Gipsy engines manufactured by the de Havilland Aircraft Company, the design following the Gipsy Major to fill a need for a higher power unit. The design of this engine follows closely along the well-tried lines of the Gipsy Major, and the great advantage of interchangeability has been retained in many of the important components, such as cylinders, cylinder heads and valve gear, pistons and rings, gudgeon pins, connecting rods, big end bearings, carburetter (the Gipsy Six has two A.I. 48 and the Major one) and a number of smaller parts.

This feature greatly simplifies the spares question and results in substantial economies where the two types of engine are used by one operator. The inherent smooth running qualities of the six-cylinder engine and the additional 50 per cent. greater power over the Major without the increase of frontal area, greatly appeals to the aeroplane designer.

The following is a brief specification of the Gipsy Six Series I engine :—

LEADING PARTICULARS OF THE "GIPSY SIX" SERIES I

Type : Six-cylinder, inverted, air-cooled, direct drive.

Rotation : Left-hand tractor.

Bore : 118 mm. (4·646 in.).

Stroke : 140 mm. (5·512 in.).

Capacity : 9,186 c.c. (560·6 cu. in.).

Normal B.H.P. : 185 at 2,100 r.p.m.

Maximum B.H.P. : 200 at 2,350 r.p.m.

Compression ratio : 5·25 to 1.

Weight : 450 lbs. $\pm$ 7½ lbs. less airscrew, boss and starter.

Fuel consumption cruising at 2,000 r.p.m. : 9·25 gallons per hour (approximately).

Fuel consumption cruising at 2,100 r.p.m. : 10·25 gallons per hour (approximately).

Fuel consumption at full throttle at 2,350 r.p.m. : 15·5 gallons per hour (approximately).

Cruising revolutions per minute : 1,950–2,050.

Oil consumption at 2,100 r.p.m. : 1 to 4 pints per hour (new engine).

Oil pressure : 40 to 45 lbs. per square inch (35 lbs. per square inch minimum).

Oil in circulation : 12 pints (minimum).

Carburetters : Claudel Hobson, A.I. 48.

Magnetos : Port and starboard B.T.H., M.C. 1–1, with impulse starters fitted, anti-clockwise.

Sparking plugs : K.L.G. V.12 and Lodge A.55/3 and 4.

Fuel : Minimum octane value 70 obtained by the C.F.R. motor method (modified to 260° F. mixture temperature) without the use of tetra-ethyl-lead.

Oil : Oil to specification D.T.D. 109. In addition to the above, a large range of proprietary brands are approved on which authoritative information can be obtained from the engine manufacturers.

Fuel pumps : The Amal Duplex (specially adapted for the Gipsy Six engine) is standard.

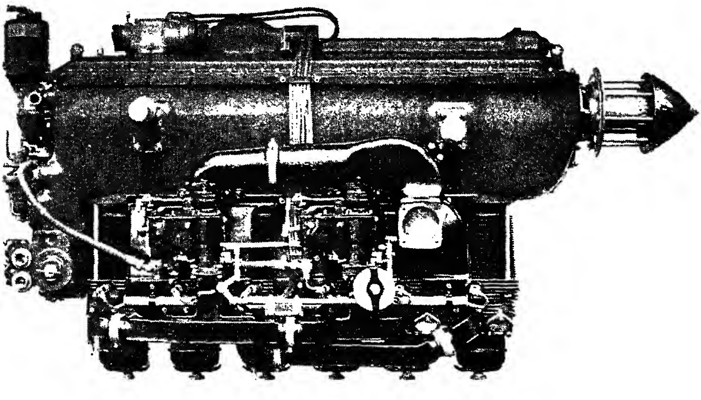


Fig. 2.—"GIPSY SIX" SERIES I AERO ENGINE.
Starboard view.

Cylinders

The cylinders are machined all over from carbon steel forgings. Special attention has been directed to the graduation of wall thickness and depth of finning in order that distortion may be avoided and an even cooling effect obtained. The ends of the cylinders project deeply into the interior of the crankcase and so provide an ample capacity for oil drainage without danger of flooding the pistons. An oil-tight joint is assured by the use of a dermatine ring which is trapped in a recess between the cylinder flange and the crankcase face. The exposed surfaces of the cylinders are specially treated against corrosion. The cylinders are interchangeable with the Gipsy Major.

Cylinder Heads

Detachable heads cast in aluminium bronze are held to the cylinder barrels by long high-tensile steel studs extending from the crankcase. A gas-tight joint is maintained between the head and barrel by the interposition of a copper and asbestos washer located in a recess in the cylinder head. The two valves for each cylinder are arranged vertically and have seatings machined directly in the material of the cylinder head.

Dual ignition is provided for each cylinder by two 12-mm. sparking plugs which are located one on either side of a compact combustion chamber. The excellent form of the cylinder head permits of smooth but rapid combustion. The finning has been carefully arranged so that,

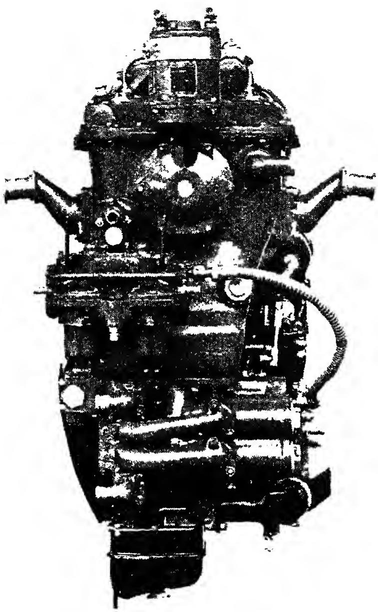


Fig. 3.—" GIPSY SIX " SERIES I AERO ENGINE. Rear view.

with the adequate area provided, effective cooling is a straightforward matter on any aeroplane. The cylinder heads and valve gear are interchangeable with the Gipsy Major.

Pistons

Slipper type-cast in heat-treated aluminium alloy. The piston is so designed that the thrust from the crown is taken direct to the gudgeon pin bosses and is not transmitted *viâ* the skirt. Fully floating gudgeon pins are located at each end by external circlips and washers. Three piston rings are fitted below the gudgeon pin on each piston. The ring nearest the gudgeon pin is of the scraper type and contributes to the low oil consumption of this engine. The pistons are interchangeable with the Gipsy Major.

Connecting Rods

Of robust design, are machined from forgings. The big end is exceptionally rigid, being clamped by four high tensile bolts. A bronze shell, lined with white metal, constitutes the big-end bearing. The connecting rods are interchangeable with the Gipsy Major.

Crankshaft

The crankshaft is machined all over from a nickel chromium alloy steel forging and is balanced statically and dynamically. It rotates in eight, steel-backed, white-metalled, main bearings. Two ball-thrust bearings are provided near the front end to locate the shaft and transmit fore and aft loads arising from the airscrew. The ample support provided and the rigid construction employed ensure perfect alignment and make

Fig. 4.—"GIPSY SIX" SERIES I AERO ENGINE.
The crankshaft.

for smooth running and long life. The journals and pins are drilled for lightness and lubrication. All main bearings are fed continuously with oil under pressure.

Airscrew Boss

The airscrew boss is fitted on a tapered extension of the crankshaft and is driven by two keys. The airscrew itself is positioned by the central hub of the airscrew boss and is driven by eight through-bolts passing between the front and rear airscrew boss flanges. As the front flange plate is *positively driven*, the eight bolts are relieved of unnecessary stress while transmitting the drive from crankshaft to airscrew. Positive means of locking the airscrew nuts are provided within a quickly detachable spinner located on the front plate.

As indicated in the Air Ministry Notice to Aircraft Owners and Ground Engineers No. 16 of the year 1935, certain designs of wooden airscrews developed cracks in hub bore, hub faces or blade roots, making periodical inspection necessary. To minimise this disadvantage a new airscrew boss on the engine was introduced having larger dimension between the flanges to allow the airscrew designer to increase the amount of wood in the hub and blade roots. Engineers are advised to eliminate the old type airscrew as soon as possible, when the old type boss can be converted in accordance with Drg. SK. 5327, a copy of which can be asked for when the parts are ordered from the engine makers. The two types of boss can be identified by measuring the space between the flanges. The old boss is dimensioned 100 mm. and the new 125 mm. The old boss is retained as standard for Fairy Reed metal airscrews, although a number of these metal airscrews have been made to special order with wide hubs to fit the new bosses.

Crankcase and Top Cover

The crankcase is cast in *elektron* and, as *the main bearings lie some distance below the joint face*, an exceptionally deep and rigid construction is obtained. Each intermediate bearing is supported by a stiff cross-

Fig. 5.—" GIPSY SIX " SERIES I AERO ENGINE.
Plan view of the top cover.

member extending right across the crankcase. The main bearing shells are retained by separate caps, which, being readily accessible by removal of the top cover, facilitate assembly, inspection and overhaul. There is *no separate timing case* in the usual sense and the rear of the crankcase is formed with an enlargement to provide a small oil sump. Appropriate facings are provided on the crankcase for bearer feet, breather, fuel pumps, oil pumps and filters, tachometer drives and engine starter. The top cover is also cast in elektron and, besides forming a cover to close the top of the crankcase, serves as a mounting for the magnetos and distributors.

Camshaft and Valve Operation

The camshaft is supported by seven bearings on the port side of the engine and operates directly on hardened steel tappets. The motion is transmitted to the valves by tubular duralumin or steel push rods and steel rockers. The bushed rockers oscillate on a hardened spindle which is attached to the cylinder head by a stout steel bracket. A simple means of adjusting the valve clearance is provided by a movable screw with locknut accessibly mounted on the push rod end of the valve rocker. All striking parts of the valve gear are hardened and are readily replaceable. The whole of the gear is totally enclosed and is lubricated by splash from the rockers dipping in an oil bath provided in the valve casing covers. Owing to the exclusion of dust and to the excellent lubrication provided, wear of the moving parts is very small indeed after prolonged running.

Timing Gears and Auxiliary Drives

The camshaft and all auxiliaries are driven from a gear wheel mounted on the front end of the crankshaft between a ball thrust bearing and first crank-throw. This is the steadiest point in the airscrew-crankshaft system and provides the smoothest drive for the accessories. From the crankshaft gear the drive, in this instance, is taken *viâ* a train of hardened

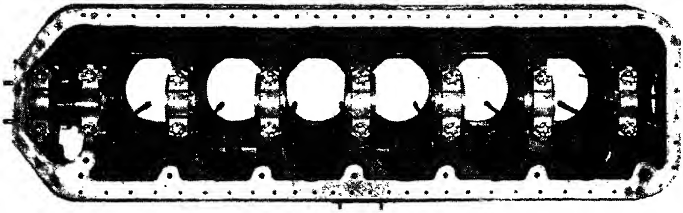


Fig. 6.—" GIPSY SIX " SERIES I AERO ENGINE.
Plan view of the crankcase.

and profile ground gears downwards to the camshaft and upwards to a long shaft mounted longitudinally inside the top cover. This fore-and-aft shaft runs at 1·5 crankshaft speed and at its rear end meshes with gears driving the two magnetos and their separate distributors. A bevel gear situated on the rear end of the camshaft drives a vertical shaft connected at its lower end to the oil pumps. The camshaft also provides drives for the dual fuel pumps and tachometer connections situated on the rear wall of the crankcase.

Lubrication

The oil pumps and filters form detachable units bolted on the rear end of the crankcase. A gear type pump draws oil from a separate tank and delivers under pressure to an Autoklean filter which ensures the removal of the finest particles of foreign matter before passing the oil into the engine.

A fine gauze filter protects the suction side of the pressure pump while the main oil pressure is regulated to 40/45 lbs. per square inch by an adjustable relief valve.

From the pressure filter, the oil divides into two streams. The main stream flows upwards to the top cover and along a cast-in gallery connected by drillings to the crankshaft main bearings. Thence the oil passes into the crankshaft and so through the hollow journals and crank pins to the big ends.

Holes are drilled in the big-end bearing and connecting-rod caps, from which oil is thrown on to the cylinder walls and pistons. This arrangement is particularly useful at starting, as proper lubrication of the pistons is established during the first revolutions of the engine. Moreover, the supply of lubricant to the cylinder walls is maintained, irrespective of wear and clearance in the main bearings. The spray thus created inside the crankcase serves to lubricate the cams and tappets,

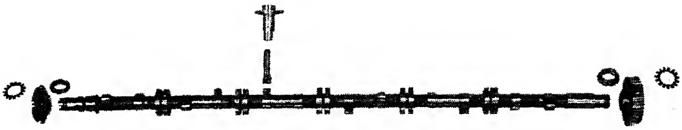


Fig. 7.—" GIPSY SIX " SERIES I AERO ENGINE.
The camshaft gear and tappet.

and as a good deal of it ultimately comes into contact with the walls of the top cover, a useful cooling effect is obtained. The second stream passes through a balanced piston mechanism which automatically reduces the pressure to approximately 15 lbs. per square inch.

Oil at this reduced pressure is used to lubricate the camshaft, top magneto drive shaft and the various accessory drives. Thus, while every important bearing is pressure lubricated, the flow of oil is not excessive, and very little external cooling suffices to maintain reasonable working temperatures for the lubricant.

After passing through the engine, the oil collects in the space formed by the extension of the cylinders inside the crankcase and is drained away by two scavenger pumps. These pumps are arranged in tandem with the pressure pump and each is provided with a detachable suction filter of fine-mesh gauze. From these filters internal passages communicate with the front and rear of the crankcase, thus ensuring that the engine is definitely drained of all surplus oil whatever its attitude in flight.

On the inboard engines of the D.H. 86 and the Percival Gull, where the oil tank is situated in an extremely low position, instances have occurred of difficulty in obtaining and maintaining a steady oil pressure when starting up, particularly after the suction oil filter has been cleaned and a certain amount of air has been introduced into the system.

The method of dealing with this when it has occurred is, of course, to prime the filter casing with oil once or twice until the pressure is maintained. This, naturally, has been looked upon as an unsatisfactory procedure and can only be treated as a temporary expedient.

The matter has been investigated and a modified filter casing cap and inlet connection has been evolved to eliminate the partial air lock which is occurring.

If symptoms as described are experienced, the engine manufacturers should be communicated with, giving full particulars as to installation and history of engine.

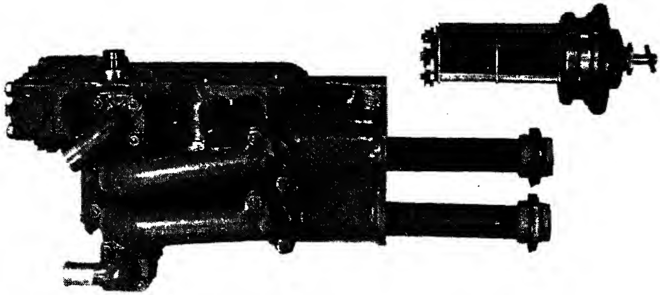


Fig. 8.—" Gipsy six " series i aero engine.
The oil pump unit, showing the filters withdrawn.

Ignition

Is provided by two B.T.H. M.C. 1 magnetos mounted longitudinally on the crankcase top cover. In this position the magnetos are particularly accessible, add nothing to the length of the engine and conform very well to the general shape of the cowling. The magnetos are driven by profile-ground spur gears meshing one on either side of a corresponding central driving gear mounted on the long top shaft previously referred to. Each magneto has its own Simms flexible vernier coupling and is provided with an improved type of impulse starter. This device ensures that the magneto delivers a strong spark at slow revolutions and so facilitates starting. The high tension current from the magnetos is taken to two separate distributors arranged just forward of the magnetos themselves and driven at half engine speed from the longitudinal top shaft.

Where radio equipment is to be installed on the aeroplane specially screened magnetos, distributor and high tension leads can be provided. The magneto controls are interconnected with the throttle controls so that ignition is automatically retarded for starting and slow running. There is also a slight retarding towards full throttle to minimise the chances of detonation at full throttle low revs. when taking-off and climbing.

On later production the holes in the base of the magnetos have to be slotted sufficiently to allow the sliding of the magneto to rotate or change the Simms flexible coupling. This greatly simplifies the timing operation or changing of a deteriorated coupling.

Induction System

Mixture is supplied by two Claudel Hobson A.I. 48 down-draught

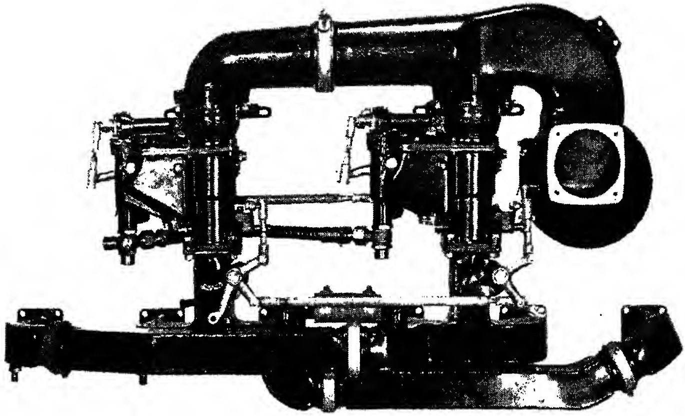


Fig. 9.—" GIPSY SIX " SERIES I AERO ENGINE.
The air intake, carburetter, and induction pipes.

carburetters situated on the starboard side of the engine. Each carburetter supplies a horizontal manifold feeding three cylinders. The air for combustion is drawn into the carburetter through a special air-intake system designed to avoid all freezing troubles without adverse effects as regards maximum power. Under normal cruising conditions (when freezing is most likely to occur) hot air is taken from the vicinity of the cylinders and led through a flame-trap direct to the carburetters. When, however, maximum output is required, the resistance of a flame-trap and a high induction temperature would somewhat reduce the horsepower obtainable. Under these circumstances, therefore, a throttle-operated valve closes communication between the flame-trap and the carburetter and at the same time opens a duct communicating with the slipstream through a normal type of carburetter air intake.

On the earlier engines this valve or flap controlling the warm or cold intake was spring loaded to the warm air position. As this flap is interconnected with the throttle control, the maximum strength of the spring is limited by the additional loading which can be put on the operation of the throttle controls, and in the case of high-speed aeroplanes or when airscrews are fitted demanding a large throttle opening to maintain normal cruising revolutions, the spring is almost in balance and a proportion of cold air may be admitted due to the flap leaving its seating.

In the course of normal development later production engines are now fitted with a cam-operated flap which is not only positively opened

and shut with the movement of the throttle, but also has the advantage of remaining closed to cold air for a much larger range of the throttle opening.

The induction pipe drains on the earlier engines were two in number and taken separately from the rear branch of the front and rear sections of the induction pipe respectively. Operation and development experience showed, however, that improved starting can be obtained by a re-arrangement, which reduces the leaks into the induction system from two to one. An elbow is therefore fitted to the front drain, and from this the drain pipe is taken to a tee-piece on the rear drain, and so led away by one pipe instead of two. The hole in the branch of the tee-piece which takes the drain-away pipe, is of small size, and as this is a leak into the induction system must on no account be enlarged, as this would be detrimental to the mixture distribution. As this small hole is continually washed by the fuel, there is little tendency for this to become stopped, but should it be noticed that the drain is not flowing freely when the carburetter is flooded on starting up, this should be examined and cleared.

Excessive flooding of the carburetter should be avoided, which will also minimise the fire risk.

Starting

Provision is made on the rear wall of the crankcase for the attachment of the 12-volt Rotax Eclipse Type Y. 150 starting unit. On closing a contact in the cockpit, this unit engages with a dog on the rear end of the crankshaft and an electric motor rotates the engine through gearing at sufficient speed to ensure satisfactory starting under all conditions. The dog coupling is automatically disengaged as soon as the engine fires.

Fuel Pump

A fuel supply to the carburetters at constant pressure is provided by a Duplex Amal fuel pump which is attached to a facing at the rear end of the crankcase, and is driven by a slotted tubular coupling from the end of the camshaft. Levers on the pump provide means of filling the carburetters for starting purposes and also allow each section of the pump to be checked for correct operation when the engine is running. This pump is of the diaphragm type, and the design renders the provision of a release valve unnecessary.

ENGINE INSTALLATION

Engine Mounting

Four vertical facings are provided on the crankcase for the attachment of engine feet. A spigot is provided in each of these facings, and the engine foot should fit in this spigot so that the shear load is taken off the four studs provided for fixing the engine feet.

Various types and lengths of engine feet can be supplied. These feet are arranged for trunnion fixing and are intended to be mounted in rubber blocks. The method of mounting these rubber blocks in their housings has been found to have a considerable bearing on the amount of vibration transmitted to the airframe. It has been found in practice that the best results are obtained with a very slight gap between the clamp plate and the top of the rubber block. The rubber must not be compressed.

It is important that all parts of the engine feet clear the rubber block support brackets by at least $\frac{1}{8}$ in. or 3 mm., so that the engine is entirely supported by the rubber blocks.

Fuel System

The fuel pipes which are attached entirely to the structure of the aeroplane can be run in copper tubing, and, unless there is considerable relative movement between the parts of the structure, no flexible joints are necessary. The joints of the pipe can be made by A.M. type metal couplings or brazed nipples and union nuts. Where the fuel pipe crosses from the structure to fuel pump a flexible pipe such as "Petroflex" or "Superflexit" should be used.

Where rigid fuel pipes are used, these should be well supported so that no vibration is set up caused by their own weight.

Under no circumstances should the minus pressure on the inlet side of the fuel pump, caused by restriction or low fuel tank position, exceed $1\frac{1}{2}$ lbs. Should this figure be exceeded trouble will probably be experienced by gas locking in the fuel pumps. The amount of depression which can be put on the fuel before the formation of gas commences is affected by temperature, altitude and the vapour pressure of the fuel. Should it be intended to operate the aeroplane under conditions and using a fuel which all tend to the formation of gas the minus pressure on the fuel pump inlet should be kept to the absolute minimum, even less than the figure quoted above if at all possible.

Magneto Wiring

The earthing terminals on the contact breaker covers should be connected up to a suitable duplex switch, so that the magnetos can be earthed separately for test purposes.

Oil System

A nut and nipple is provided, at the rear end of the main oil passage in the top cover, for the attachment of a pipe leading to the pressure gauge. A fuel-resisting rubber connection should be provided in this pipe as close as possible to the connection on the engine, and the pipe should then be clipped to the aeroplane structure. Coils to take up vibration in this pipe are not necessary, and generally are troublesome, due to vibration caused by their own weight. Should a long pipe be

necessary, owing to structural requirements, it is as well to fit piping having a large bore, as, otherwise, in cold weather the gauge will not respond quickly to varying pressures in the engine. In extreme cases it is advisable to consider the use of a gauge of the Negretti and Zambra or Amiot type which are very little affected by low temperatures. A pressure gauge reading 0–60 or 0–100 lbs. per square inch should be used, as with any gauge reading higher than this the scale will be rather close.

The pressure gauge connection on top cover of early engines was screwed 10 mm. diameter and on later engines a more robust job was made 12 mm. diameter. Engineers with the early engines are advised to fit the later type when their engines are being overhauled.

The oil delivery pipe to the engine is connected to the top elbow on the oil suction filter unit using a joint of fuel-resisting hose. This pipe, if of copper or steel, should be not less than $\frac{7}{8}$ in. outside diameter, or if a flexible tubing such as " Superflexit " is used this should be at least $\frac{7}{8}$ in. bore.

The oil return pipe from the engine is connected to the lower elbow on the oil pump unit and the same remarks as given for the delivery pipe apply except that the minimum size is $\frac{5}{8}$ in.

If steel or copper oil pipes are used, the following points should be noted.

Two hose joints should be fitted in each pipe between the engine and airframe structure. The one joint on the pump elbow is not sufficient ; an additional joint is necessary close to the joint where the pipe is clipped to the structure. Before fitting hose joints the copper or steel tubing should be beaded and free from any sharp edges, etc., which will tend to damage hose connections internally when these are being fitted.

As the engine is equipped with dual scavenge pumps the position of the oil tank is comparatively unimportant. Should the oil tank be very much above the oil pump level it may be necessary to provide a cock which can be shut off when engine is standing to stop oil from draining from the tank to the engine. This cock should be connected to the engine switches or fuel cock to avoid the possibility of the engine being run with the oil cock turned off.

The oil thermometer, if fitted, should be in the oil *inlet* pipe to engine.

Engine Controls

The throttle lever in the cockpit should be connected up to the bell crank or pulley provided on the short lay-shaft situated at the rear of the starboard side rear engine foot. For single-engined aeroplanes it will generally be found convenient to use rods but for multi-engined aeroplanes where double tension cables are more satisfactory the pulley fitting can be provided in place of the plain bell crank. The mixture control lever should be connected up to the pick-up hole provided in the bell crank on the rear carburetter. It is important that the controls in

the aeroplane give slightly more than sufficient movement in order to give full travel to the controls on the engine. This will ensure control levers being brought positively up against the stops on the carburetters, magnetos, etc.

During normal operation and maintenance there is certain difficulty in retaining the free working of the cone type mixture control valve. There is, however, a lubricant which will minimise the amount of attention required to keep these valves free and is known as "Autrosal," which is a colloidal graphite, put up in collapsible tubes. "Autrosal" should be well lapped into the surface of the valve, which should then be finally assembled with a surplus.

Tachometer Drive Attachments

Attachments are provided on the engine for dual engine speed drives. Should only one drive be used, the spare attachment should be blanked off with a cap which can be supplied.

To obtain steady readings on the tachometer the run of the flexible drive should be as free from bends of small radius as possible. The observance of this precaution will also prolong the life of the flexible shaft as bends impose a considerable amount of stress on this part.

Starters

The engine can be supplied fitted with a Rotax electric starter.

Should no starter be fitted, the facing on the crankcase which normally takes the starter is covered by a blanking plate.

Airscrew Boss

An airscrew boss complete with spinner is supplied as standard. When Schwarz protected airscrews are fitted, a friction disc must be inserted between the rear face of the airscrew and the front face of the boss flange.

Exhaust System

The following points should be noted in connection with exhaust manifolds :—

The pipes from each cylinder should be of the same diameter as the hole in exhaust flange provided with engine. The manifold can be of tapered or parallel form, but should measure at least $2\frac{3}{4}$ in. outside diameter at the rear end where it joins the extension pipe which should also be not less than $2\frac{3}{4}$ in. outside diameter. If the pipes from cylinders to manifold are short, expansion pipes should be provided in the manifold. The whole of the manifold and as much of the branches as possible should be outside cowling.

Should a long extension pipe be fitted, allowance must be made for expansion, either by sliding joints or by brackets so designed as to allow

the extension pipe to move, thereby avoiding any strain on the exhaust manifold.

If small holes or slots are provided in the extension pipe for the final escape of gas, with a view to reducing noise, the total area of these should be considerably larger than the area of the extension pipe, otherwise a loss of power will result, owing to the back pressure set up by this form of outlet. This back pressure as well as causing a loss of power may cause the engine to overheat, and considerable gas leakage from the joints in the manifold or extension pipe with attendant blowing out troubles.

Crankcase Breather

An attachment is provided for a breather pipe on the rear of the crankcase. The breather pipe should not be less than 1 in. outside diameter and should preferably be led to a point outside the cowling, but should not project, as in cold climates ice tends to form and block this pipe. A certain amount of oil vapour comes from this breather and tends to make the engine bay dirty if this pipe finishes inside the cowling. The end of this pipe should be so arranged that in no conditions of flight is it under a positive pressure, a slight negative pressure is preferable. The breather pipe should be connected up to the attachment by a fuel-resisting rubber joint.

"GIPSY SIX" SERIES II AERO ENGINE

CONSTRUCTION AND ASSEMBLY

By A. J. Brant,
Service Manager, de Havilland Aircraft Co. Ltd.

THE Gipsy Six Series II aero engine is the logical outcome of the advent of the controllable-pitch airscrews, permitting the advantage of higher compression ratios and rating for a higher continuous output.

It is an air-cooled in-line inverted engine.

The engine, a development of the well-known and tried Gipsy Six, is designed to operate continually at a higher continuous power output for level cruising and at higher r.p.m. with considerably increased power for take-off and climb.

Other special features of the Series II include forged pistons, a new type crankshaft designed to drive both controllable and fixed-pitch airscrews and the oil-pressure system which operates the airscrew pitch movement. To permit, if necessary, the use of leaded fuels, the cylinder heads are of aluminium alloy with inserted high-expansion steel valve seats; and stellited exhaust valves and bottom-seated 14-mm. sparking plugs are used for similar considerations.

The opportunity has been taken to embody new auxiliary drives, one of which operates a vacuum pump to provide the power for the gyros of navigating instruments. Another is available for a constant-speed airscrew governor, while a third will be introduced on later engines for an electric generator of up to 500 watts output. This is arranged in such a manner that the exact location of the generator can be varied within limits to suit the engine installation scheme.

The compression ratio is 6 to 1, compared with 5·25 to 1 of the Series I Gipsy Six, and results in a lower specific fuel consumption.

Note

Owing to misunderstandings having arisen due to the expressions "Top dead centre" and "Bottom dead centre" on the inverted type of engine, these positions are now referred to as "Inner dead centre" (piston farthest from cylinder head) and "Outer dead centre" (piston nearest to cylinder head).

CONSTRUCTION

Cylinder Head

This is an aluminium alloy casting to material specification L. 11, which is held to the cylinder barrel by four high tensile steel studs screwed

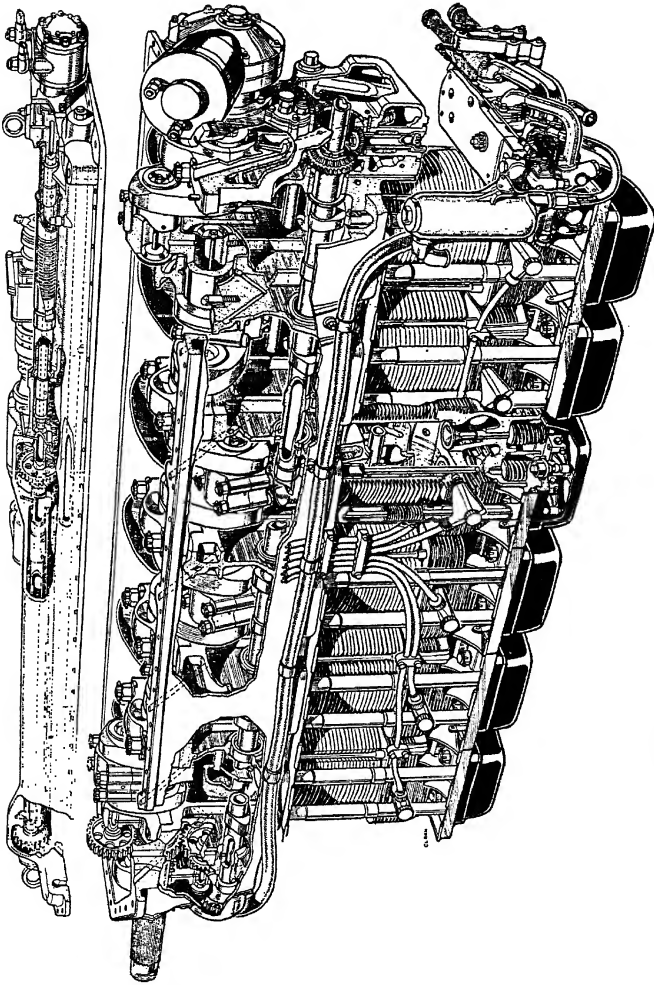


Fig. 1.—CUT-AWAY VIEW OF "GIPSY SIX" SERIES II ENGINE. (*By courtesy of "Flight."*)

at their upper ends into the crankcase. The joint between the head and the cylinder is made by a copper asbestos washer which fits into a recess in the cylinder head. Flanged bronze guides are fitted to one inlet and one exhaust valve, the high expansion steel seatings to specification "FIRTHS, N.M.C." being shrunk and peened into position in the cylinder head. Dual ignition is provided by two 14-mm. sparking plugs, fitted one in each side of the cylinder head. The cylinder heads are provided with liberal fin area to ensure adequate cooling when the engine is installed in the aeroplane. The inlet and exhaust ports are arranged on the starboard side of the engine.

Cylinder

This is a carbon steel forging to specification S. 70, machined externally to form cooling fins and ground internally, special attention being directed to the graduation of wall thickness and depth of finning in order that distortion may be avoided and an even cooling effect obtained. It is afterwards specially treated for protection against corrosion. An intermediate flange is formed on the barrel, together with spigots at either end. One spigot fits the head, the joint here being made between the seating and the end of the barrel by an intervening copper asbestos washer. The other spigot fits into the crankcase to the extent of the flange on the barrel, an oil-tight joint being formed by compressing a dermatine ring between the radius of the flange and the chamfered edge of the crankcase bore.

Piston

The pistons are machined all over from a forging of aluminium alloy, specification D.T.D. 132 and is of the slipper type, so designed that the stress from the crown is taken direct to the gudgeon pin, which floats in both the piston and the small end of the connecting rod and is retained by external circlips and washers at each end. Three rings are fitted in each piston, the inner ring being of the scraper type which scrapes surplus oil from the cylinder wall and deflects it through a series of small drilled holes through to the inside of the piston, and so back to the crankcase.

Connecting Rod

This is a D.T.D. 130 alloy forging of H-section. The big end is split and houses the steel-backed white metal split bearing which is clamped by four high tensile bolts. Leak holes are provided in the cap of the rod and bearing to distribute oil for cylinder and tappet lubrication. The small end is plain and unbushed, and drilled to supply oil to the gudgeon pin.

Crankshaft

The crankshaft is a nickel chromium alloy steel forging to specification S. 81. The webs support in three planes, 120 degrees apart, the six crankpins. The journals and crankpins are bored and capped and the webs drilled, except Nos. 1 and 12, to afford pressure feed lubrication to the connecting rod big ends. The front end of the crankshaft is splined for the reception of the airscrew hub. The crankshaft drives the camshaft and magnetos from a gear located on the front end.

Airscrew Hub (Fixed Pitch)

The airscrew hub is fitted over the splined extension of the crankshaft, and centralised by means of a split steel cone and an aluminium bronze cone at front and rear respectively. When a wooden airscrew is fitted it is centralised on the hub by means of a narrow raised land which is situated on the centre line of the airscrew. This narrow centralising land is used to overcome splitting of the airscrew boss which can occur if a wooden airscrew contacts on to its hub. When a metal fixed pitch airscrew is fitted, a hub can be supplied on which there is no narrow land as described above, the airscrew fitting over and centralising on to the hub in the usual manner.

The front plate is splined to the central hub of the airscrew boss, therefore, being positively driven, the eight bolts are relieved of unnecessary stress.

Crankcase and Top Cover

These components are cast in magnesium alloy to specification D.T.D. 281 and, as the main bearings lie some distance below the joint face, an exceptionally deep and rigid construction is obtained. Each intermediate bearing is supported by a stiff cross-member extending right across the crankcase. The main bearing shells are retained by separate caps, which being readily accessible by the removal of the top cover, facilitate assembly, inspection and overhaul. There is no separate timing case in the usual sense, and the rear of the crankcase is formed with an enlargement to provide a small oil sump. Appropriate facings are provided on the crankcase for bearer feet, breather, fuel pumps, oil pumps and filters, tachometer drives and engine starter. The top cover is also cast in elektron and, besides forming a cover to close the top of the crankcase, serves as a mounting for the magnetos, distributors, vacuum pump, and gearbox for driving the airscrew governor.

Camshaft

This is of steel with twelve integral cams, and is borne in bearings in the lower part of the crankcase on the port side. The five intermediate journals run in bearings bored directly in the cross webs of the crankcase and are of large diameter to enable the camshaft to be withdrawn to the

front. The front and rear bearings are of elektron and are bolted to the crankcase. The bearings are lubricated by oil carried under low pressure through the hollow camshaft. The camshaft is driven off the front end of the crankshaft by a spur gear which is keyed to the camshaft, having four vernier keyways for timing purposes.

Valve Operating Gear

Each cam operates a sliding tappet which lifts the valve by means of the usual tappet rod and rocker mechanism, the closing of the valve and the return stroke of the tappet being accomplished by the action of the valve spring. The tappet is square ended at the cam end to prevent rotation and is bored from the other end for the greater part of its length and through the side at the square end, and fitted with a ball end to engage the tappet rod. The tappet reciprocates in a flanged guide housed in the crankcase and bolted to the lower face thereof. The tappet rod is of steel, fitted at the upper and lower ends with a ball end and cup respectively. The rocker of steel pivots through an intervening fixed phosphor bronze bush on a hardened steel spindle held in a stamped steel bracket bolted to the lower face of the cylinder head.

At the push rod end, the rocker is tapped to receive a hardened steel screwed cup end and locknut, by means of which tappet clearance is adjusted. The other end of the rocker is fitted with a riveted-in hardened steel pad. A telescopic cover encloses the tappet rod and seats outwardly under the action of an enclosed central spring against the tappet guide flange at the crankcase and a facing on the top side of the cylinder head. The valves, rockers, etc., are completely enclosed by a cast elektron box held into position on the underside of the cylinder head by a cap nut.

Valves

The valves are of steel, the exhaust being Hadfield's new era D.T.D. 49A, and the inlet S. 62. The exhaust valve seat is stellited, a process which is found to be essential when running engines on a fuel containing tetra-ethyl-lead. The ends of both the exhaust and inlet valve stems are also stellited in order to withstand wear. Both valves have tulip-shaped heads, the inlet being slightly larger. Double concentric valve springs are fitted between the flange of the valve guide and the valve stem collar which in turn is held in position on the valve with split taper collets.

Timing Gears and Auxiliary Drives

The camshaft and all auxiliaries are driven from a gear wheel mounted on the front end of the crankshaft between the ball thrust bearing and the first crank-throw. This part of the crankshaft provides the smoothest drive for the accessories, giving a drive free from all undue fluctuations, which means long life and satisfactory service from the units involved. From the crankshaft gear the drive is taken *viâ* a train of hardened and

profile-ground gears, downwards to the camshaft and upwards to a land shaft mounted longitudinally inside the top cover. This longitudinal shaft runs at one and a half crankshaft speed and at its rear end meshes with gears driving the two magnetos and their separate distributors.

A bevel gear situated on the rear end of the camshaft drives a vertical shaft connected at its lower end to the oil pumps. The camshaft provides drives for the dual fuel pump and the tachometer drive situated on the rear wall of the crankcase. When a vacuum air pump for the purpose of driving flying instruments and/or a gearbox for driving an airscrew governor, is required on the engine, a drive is supplied taken from the magneto driving gear in the centre of the top cover, *viâ* an aluminium cover tube between the magnetos, and so to an extension at the rear of the top cover which is provided with a facing to take the vacuum air pump and the gearbox. If this drive is not supplied, the engine is fitted with a different pattern magneto driving gear and devices for blanking off the drive holes in the top cover.

Induction System

Mixture is supplied by two Claudel Hobson A.I. 48 down-draught carburetters situated on the starboard side of the engine. Each carburetter supplies a manifold feeding three cylinders. The air for combustion is drawn into the carburetter through a special air-intake system designed to avoid all freezing troubles without adverse effects as regards maximum power. Under normal cruising conditions, when freezing is most likely to occur, hot air is taken from the vicinity of the cylinders and led through a flame trap direct to the carburetters. In this way a nicely warmed induction is obtained, resulting in excellent smoothness and economy of operation. When, however, maximum output is required, the resistance of a flame trap and a high induction temperature would somewhat reduce the horse-power obtainable. Under these circumstances, therefore, a flap in the air-intake castings closes the passage to the flame trap inside the engine bay and at the same time opens a duct communicating with the usual external air intake in the slipstream. When the engine is being used with a fixed pitch airscrew this change-over flap is interconnected with the throttle control, so that at full throttle, for take-off and climb, it is open to the external intake and changes over to the internal intake when the throttle is closed to the normal cruising position. When the engine is fitted with a controllable-pitch airscrew the flap is manually controlled by the pilot, and for his guidance a thermometer is also fitted in the air intake.

Lubrication

The oil pumps and filters form detachable units bolted on the rear end of the crankcase. A gear type pump draws oil from a separate tank and delivers under pressure to an "Auto-Klean" filter which ensures the

removal of the finest particles of foreign matter before passing the oil into the engine. A fine gauze filter protects the suction side of the pressure pump while the main oil pressure is regulated to 40–45 lbs. per square inch by a relief valve. From the pressure filter, the oil divides into two streams. The main stream flows upwards to the top cover and along a cast-in gallery connected by drillings to the crankshaft main bearings. Thence the oil passes into the crankshaft and so through the hollow journals and crankpins to the big ends. Holes are drilled in the big end bearing and connecting rod caps, from which oil is thrown on to the cylinder walls and pistons.

This arrangement is particularly useful on starting, as proper lubrication of the pistons is established during the first revolutions of the engine, moreover, the supply of lubricant to the cylinder walls is not affected to a large extent by wear of the bearings. The spray thus created inside the crankcase serves to lubricate the cams and tappets, and as a good deal of it ultimately comes into contact with the walls of the top cover, a useful cooling effect is obtained. The second stream passes through a balanced piston mechanism which automatically reduces the pressure to approximately 15 lbs. per square inch.

Oil at this reduced pressure is used to lubricate the camshaft bearing, top magneto drive shaft and the various accessory drives. Thus, while every important bearing is pressure lubricated, the flow of oil is not excessive and very little external cooling suffices to maintain reasonable working temperatures for the lubricant. After passing through the engine, the oil collects in the space formed by the extension of the cylinders inside the crankcase and is drained away by two scavenge pumps. These pumps are arranged in tandem with the pressure pump and each provided with a detachable suction filter of fine-mesh gauze. From these filters internal passages communicate with the front and rear of the crankcase, thus ensuring that the engine is completely drained of all surplus oil whatever its attitude in flight.

Oil Filters

The two scavenge filters and the main pressure filter are contained in an elektron casting attached to the rear of the crankcase. The suction oil filter, also cast in elektron, is supported by a sheet metal bracket bolted to the crankcase. The filters are accessible for cleaning by undoing the hexagon caps. As the pressure filter is of the " Auto-Klean " type, it is only necessary to dismantle the filter for cleaning after every 250 hours' flying. The bar, however, should be turned frequently in order to clear the filter.

GENERAL DATA

TYPE : Six-cylinder-in-line, inverted, air-cooled, direct drive, dry sump.
STANDARD ENGINE : Suitable for use with fixed pitch airscrew.

OPTIONAL ALTERNATIVE: Provision for use of D.H. controllable two-pitch or constant speed airscrew.

NUMBERING OF CYLINDERS: Airscrew 1, 2, 3, 4, 5, 6.

FIRING ORDER: 1, 2, 4, 6, 5, 3.

BORE: 118 mm. (4·646 in.).

STROKE: 140 mm. (5·512 in.).

COMPRESSION RATIO: 6 to 1.

DIRECTION OF ROTATION OF AIRSCREW: Left-hand tractor.

ELECTRIC STARTER: Rotax Eclipse Y. 150.

FUEL PUMP: Amal "Duplex."

CARBURETTER: Two; Claudel Hobson Type A.I. 48.

TACHOMETER DRIVE: Single engine speed.

FLAME TRAP: Amal.

IGNITION: Unscreened B.T.H. M.C. 1 magnetos and K.L.G. V. 14/1 or Lodge A. 14/1 plugs.

AIRSCREW BOSS: Fixed pitch.

CRANKSHAFT R.P.M.: Normal; 2,100 r.p.m.

RATED POWER AT NORMAL R.P.M.: 185 h.p. at 2,100 r.p.m.

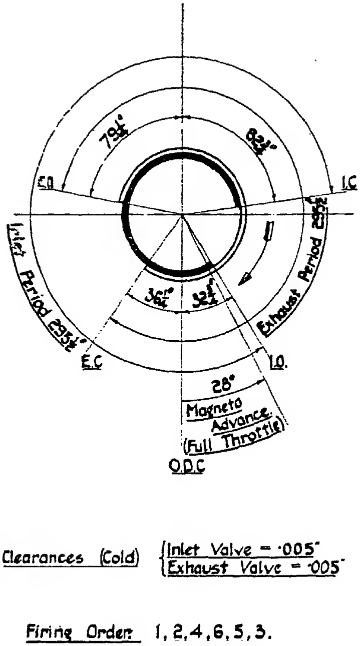


Fig. 2.—VALVE TIMING DIAGRAM FOR "GIPSY SIX" SERIES II ENGINE.

CRANKSHAFT R.P.M.: Maximum; 2,400 r.p.m.

RATED POWER AT MAXIMUM R.P.M.: 205 h.p. at 2,400 r.p.m.

WEIGHT OF ENGINE, INCLUDING THE ABOVE, AND EXCLUDING OIL, EXHAUST MANIFOLD AND ENGINE FEET: 509 lbs.

FUEL: Minimum octane No. 77, containing not more than 4 c.c. of T.E.L. per gallon.

FUEL CONSUMPTION, FULL THROTTLE AT 2,400 R.P.M.: 16¼ gallons per hour.

FUEL CONSUMPTION, CRUISING AT 2,100 R.P.M.: 11½ gallons per hour.

OIL: Oil to specification D.T.D. 109 and a range of proprietary grades also approved by the engine manufacturers.

IGNITION: Timing. Interconnected with throttle.
Timing on full throttle. 28° before outer dead centre.
Contact breaker gap. 0·011–0·013 in.
Sparking plug gap. 0·012–0·015 in.

VALVE TIMING : Inlet valve tappet clearance (cold), 0·005 in.
Exhaust valve tappet clearance (cold), 0·005 in.
Inlet valve opens. $32\frac{3}{4}^\circ$ before outer dead centre.
Inlet valve closes. $82\frac{3}{4}^\circ$ after inner dead centre.
Exhaust valve opens. $79\frac{1}{4}^\circ$ before inner dead centre.
Exhaust valve closes. $36\frac{1}{4}^\circ$ after outer dead centre.

INSTALLATION

The installation of the Gipsy Six Series II engine in a prototype aeroplane is a highly technical undertaking, and aeroplane designers and constructors have closest co-operation from the engine manufacturers, but the following notes will be of guidance and value to students, inspectors and engineers.

Engine Mounting

Four vertical facings are provided on the sides of the crankcase for the attachment of the engine feet. A turned recess is provided in each of these facings, and the engine foot spigot fits into this recess so that the sheer load is taken off the four studs provided for fixing the engine feet.

Alternative types of feet are available to suit different installations. The feet are arranged for a trunnion fixing, and should be mounted in "D" shaped rubber blocks. It can be noted here that the red rubber blocks as fitted to the engine feet are for transport purposes only, and on no account must be used in the aeroplane installation.

Cooling System

The engine will be normally enclosed by the nose cowling when installed in the aeroplane, the cooling of the engine has therefore to be arranged by special scoops and baffles. The standard air scoop supplied is fitted on the port side of the engine, beneath the aeroplane cowling. The air scoop is in two portions dividing its length, and is attached by hinge pins to plate extensions on the top of the valve rocker casings and the base of the crankcase respectively. The scoop is bowed and slopes towards the cylinders to the rear, its distance therefrom decreasing slightly from front to rear. The baffle is a slotted aluminium pressing with blank pieces located opposite the space between the cylinders, so as to cause air flow between the fins of the cylinders. The baffle is attached at its top to the crankcase, and its lower edge is secured by clips under the cylinder holding down nuts. It should be noted here that the cooling system should be such that the maximum cylinder head temperatures measured on the climb should not exceed 220° C.

Fuel System

The fuel pipes which are attached entirely to the structure of the aeroplane can be run in copper tubing, and, unless there is considerable

relative movement between the parts of the structure, no flexible joints are necessary. The joints of the pipe can be made by A.M. type metal couplings or brazed nipples and union nuts. Where the fuel pipe crosses from aeroplane structure to fuel pump a flexible pipe such as "Petroflex" or "Superflexit" should be used. All pipes, filters and cocks should have a clear bore of not less than $\frac{5}{16}$ in. inside diameter. Where rigid fuel pipes are used, these should be well supported so that no vibration is set up caused by their own weight. Under no circumstances should the depression on the inlet side of the fuel pump caused by restriction or low fuel tank position exceed $1\frac{1}{2}$ lbs. Should this figure be exceeded trouble will probably be experienced by gas locking in the fuel pumps. The amount of depression which can be put on the fuel before the formation of gas commences is affected by temperature, altitude and the vapour pressure of the fuel. Should it be intended to operate the aeroplane under conditions and using a fuel which all tend to the formation of gas, depression on the fuel pump inlet should be kept to the absolute minimum, even less than the figure quoted above if at all possible.

Ignition System

The earthing terminals on the magneto contact breaker covers should be connected up to a standard twin-knob switch and labelled to enable the magnetos to be earthed independently as required. The common earth connection on the switch is wired directly to some part of the engine and not to the airframe; this is important. To ensure safety to personnel when starting the engine by swinging the airscrew, check the L.T. earthing wires for continuity occasionally, using, if available, the standard magneto synchroniser as a continuity tester. Alternatively the check can be made by using an electric torch or hand lamp with a length of flex connecting from the earthing spring on the magneto to the switch at the cockpit. Removal of the magneto contact breaker covers will be necessary which renders the earthing switches inoperative. This is dangerous, as action of the impulse starter may start the engine should the airscrew be turned. *In no circumstances should these tests be made without* (a) *disconnecting all the H.T. leads from the sparking plugs or* (b) *removing the distributors from the magnetos.* After completing the tests leave both switches in the "OFF" position.

Oil System

A nut and nipple for the attachment of a pipe leading to the 0–60 lbs. square inch or 0–100 lbs. square inch pressure gauge or alternatively a post suitable for the fitting of a Negretti and Zambra transmitting oil pressure gauge, is provided at the rear end of the oil gallery in the crankcase top cover. When a nut and nipple is used, an approved gauze-covered, fuel-resisting rubber connection should be provided on the pipe as close as possible to the fitting on the gallery, to take up vibration.

This type of connection is preferable to a coiled pipe, as the coils are liable to vibration trouble due to their own weight. The oil delivery pipe to the engine is connected to the top elbow in the oil suction filter unit, using a P.R. rubber connection ; this pipe should be at least $\frac{7}{8}$ in. diameter bore. The oil return pipe from the engine is connected to the lower elbow in the oil pump unit, and the same remarks as given for the delivery pipe apply, except that minimum size is $\frac{5}{8}$ in. diameter. As the engine is equipped with dual scavenge pumps the position of the oil tank is comparatively unimportant. Should the oil tank be very much above the oil pump level, it may be necessary to provide a cock which can be shut off when the engine is standing to stop oil from draining from the tank to the engine. This cock should be connected to the engine switches or fuel cock to avoid the possibility of the engine being run with the oil cock off. Provision can be made in the inlet and outlet oil pipes to and from the engine respectively for the usual oil thermometer pockets which must be fitted within 10 in. of the engine itself.

Engine Controls

Engine control levers in the cockpit should be connected up to the pick-up levers provided on the engine. If the aeroplane is fitted up with pulley-operated throttle and mixture controls, the engine must be fitted up with pick-up pulleys. It is important that the controls in the cockpit give slightly more than sufficient movement in order to give full travel to the controls on the engine ; this will ensure that the controls will be brought up positively against the stops on the carburetter. The throttle and magneto controls are interconnected in such a way that when the throttle is closed, the ignition is fully retarded. As the throttle travels through the first part of its movement, the ignition is fully advanced, where it stays throughout the whole of the cruising range. During the last part of the movement the magnetos are retarded slightly, which gives a condition whereby the engine is less liable to detonate while running at slow revolutions and full throttle as during the take-off. When a de Havilland two-pitch airscrew is fitted, a control must be fitted up between the cockpit and the oil cock operating lever at the rear of the oil pump casing. If a constant speed airscrew is fitted a control must be fitted up between the pulley on the governor and the cockpit.

PERFORMANCE

A graph giving the power and throttle curves of a typical bench test and graphs Fig. 3 and Fig. 4, showing respectively the comparative power outputs available for cruising and for take-off and climb when fixed pitch and controllable pitch and constant pitch airscrews are fitted to the Gipsy Six Series II engine, accompany this article, and will enable the student, ground engineer and pilot to grasp the principles

involved and demonstrate the improvements in take-off, climb and cruising possible by the use of controllable pitch airscrews on the Series II engine.

Example "A," the fixed pitch airscrew, absorbs the full throttle power developed by the engine at the maximum permissible r.p.m. (2,400 r.p.m.) in level flight at sea level.

The cruising output (curve A, Fig. 3) is determined by the amount of throttling necessary to obtain 2,100 r.p.m. (the maximum r.p.m. for continuous cruising) and by the reduced atmospheric density at higher altitudes.

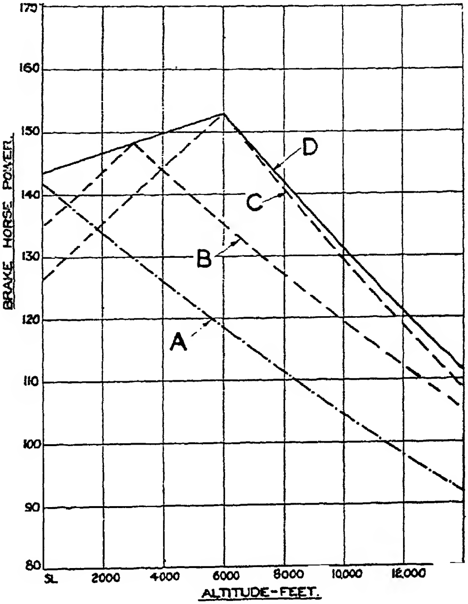


Fig. 3.—GRAPHS SHOWING COMPARISON OF CRUISING OUTPUTS AVAILABLE AT ALTITUDE WHEN USING FIXED PITCH, TWO PITCH, CONTROLLABLE OR CONSTANT SPEED AIRSCREWS.

The climbing output (curve A, Fig. 4) represents the power developed by the engine, full throttle at 2,100 r.p.m. (the maximum climbing r.p.m.) at any altitude.

The take-off output (curve A, Fig. 4) for the purpose of these comparisons is defined as the mean between the value obtained with the aeroplane on the ground and the engine running full throttle and that with the aeroplane having attained full climbing speed in flight.

Example "B," a two-pitch controllable airscrew intended for effective operation at relatively low altitudes is designed to absorb, when in its coarse-pitch position, the power developed by the engine at 2,100 r.p.m. at 3,000 feet when throttled until the induction pipe pressure is reduced to 11·7 lbs. per square inch absolute.

The cruising output with this airscrew is given by curve B of Fig. 3. Below 3,000 ft. altitude the output is limited by restricting the induction-pipe pressure to 11·7 lbs. per square inch absolute and with the engine throttled to this extent, the r.p.m. will fall slightly below 2,100 r.p.m.

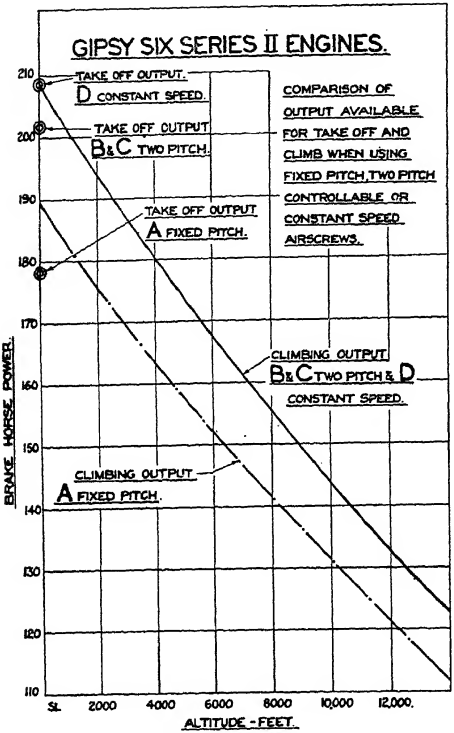


Fig. 4.—GRAPHS SHOWING COMPARISON OF OUTPUT AVAILABLE FOR TAKE-OFF AND CLIMB WHEN USING FIXED PITCH, TWO PITCH, CONTROLLABLE OR CONSTANT SPEED AIRSCREWS.

Above 3,000 ft. altitude the limitation is that imposed by throttling to the maximum cruising r.p.m. of 2,100.

The climbing output (curve B, of Fig. 4) represents the power developed by the engine full throttle at 2,400 r.p.m. at any altitude; the fine-pitch position of the airscrew is designed to absorb this output.

The take-off output is, as with airscrew A, the mean between aeroplane static and full climbing flight.

Example "C," a two-pitch controllable airscrew intended for effective operation at altitudes in excess of 5,000 ft. is designed to absorb, when in its coarse-pitch position, the power developed by the engine at 2,100 r.p.m. at 6,000 ft. with induction-pipe pressure at 11·7 lbs. per square inch absolute; this is approximately full throttle.

The cruising output with this airscrew is given by curve C of Fig. 3. Below 6,000 ft. altitude the output is limited by restricting the induction-pipe pressure to 11·7 lbs. per square inch absolute and, with the engine throttled to this extent, the r.p.m. will fall below 2,100 r.p.m. slightly at altitudes approaching 6,000 ft., but by an appreciable amount at very low altitudes. Above 6,000 ft. the engine operates at full throttle at approximately 2,100 r.p.m.

The climbing and take-off outputs with this airscrew are exactly as for airscrew B (see curve Fig. 4).

Example " D," the controllable - pitch airscrew used in conjunction with the D.H. Hamilton constant-speed governor, permits full advantage to be taken of the output of the engine under any conditions of running.

The cruising output with this combination is given by curve D of Fig. 3.

Below 6,000 ft. the engine is throttled to an induction - pipe pressure of 11·7 lbs. per square inch absolute, the governor control is set to 2,100 r.p.m., and the airscrew pitch automatically adjusts itself to any altitude to absorb the full output of the engine under these conditions. Above 6,000 ft. the engine operates at full throttle, the r.p.m. being maintained constant at 2,100 by the governor.

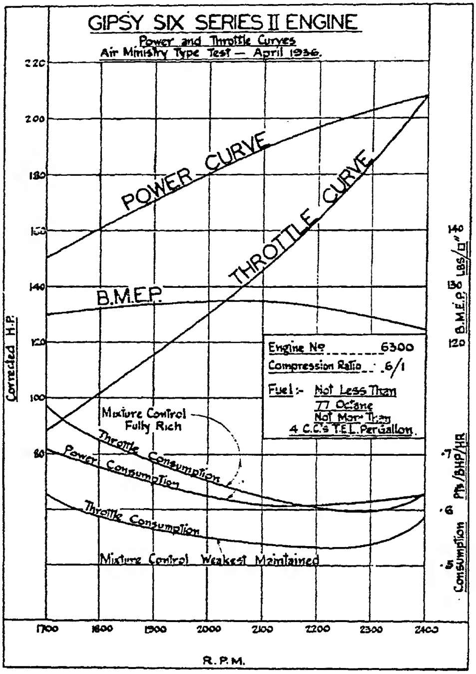


Fig. 5.—POWER AND THROTTLE CURVES.

The climbing output with this airscrew is exactly as that for the two-pitch airscrews B and C and is achieved by setting the governor to 2,400 r.p.m. and giving full throttle, but an improvement in take-off power (Fig. 4) is obtained by reason of the airscrew's constant-speed characteristic which permits 2,400 r.p.m. before the aeroplane leaves the ground.

The output shown on these curves takes no account of the effect of forward speed. In flight, when a well-designed forward facing air intake is fitted, the effect of the velocity of the intake air is to increase the altitude to which 11·7 lbs. per square inch absolute induction-pipe pressure is maintained from 6,000 ft. to about 7,000 ft. and, further, to result in a small increase in power when operation is at full throttle.

The curves Fig. 3 and Fig. 4 show at a glance the advantages to be

obtained from using de Havilland controllable-pitch airscrews on the Gipsy Six Series II engines, and the different effects obtainable from alternative pitch settings.

Thus, with a conventional fixed-pitch airscrew (curve A), the cruising performance at altitude is seriously limited by what is really an unnecessary degree of throttling of the engine, in order to hold the speed at 2,100 r.p.m. The two-position controllable airscrew C makes the most use of the engine at high altitudes and shows improved performance over airscrew A for altitudes above 2,000 ft. The coarse-pitch of airscrew C entails some loss in cruising speed below 2,000 ft.

The operator who does most of his flying at 5,000 ft. or below would be well advised to fit an airscrew similar to B. This combination may be regarded as a compromise between fixed-pitch airscrew A and coarse-pitch airscrew C.

The constant-speed device, when fitted to the de Havilland controllable-pitch airscrew, makes the best use at all altitudes of the maximum output permitted by engine type test, and shows to advantage over the two-position controllable airscrews B and C. Curve Fig. 4 demonstrates very forcibly the improvements in take-off and climb obtained by the use of controllable-pitch airscrews on the Series II engine. Actually, the improvement is even greater than that indicated by the curves, since, with most modern aeroplanes, the conventional fixed-pitch airscrew is seriously stalled at take-off. In other words, the improvement in effective thrust from using controllable airscrews is greater than the comparison of engine power suggests.

It will be noted that it is necessary to regulate the cruising output to an induction-pipe pressure in the case of all controllable-pitch airscrews. For this purpose it is essential to provide a boost gauge for each engine as standard aeroplane equipment. Throttling to the prescribed induction-pipe pressure when cruising avoids the danger of overloading the engine.

MANUFACTURING ROUTINE

MAIN ASSEMBLY OF COMPONENTS

HAVING completed the manufacture of each of the individual components we are now in a position to deal with the work of final assembly. The components to be handled are as follows :—

(*a*) Front portion fuselage.
(*b*) Rear portion fuselage.
(*c*) Stern frame, tail plane, elevators, fin, rudder and tail wheel.
(*d*) Centre plane, engine mounting, undercarriage and centre plane flaps.
(*e*) Outer planes, outer plane flaps and ailerons.

Item (*d*) is the key component for assembly, and this is set up on fixtures picking up the outer fittings on the front and rear spars (see Fig. 1). The fixtures are carefully located, so that the centre plane, when in position, is in correct alignment both laterally and also fore and aft. A point to note is that the undercarriage is not assembled during the period the centre plane is on this jig and therefore the height of the fixture is arranged to give the best accessibility for the work on this stage of

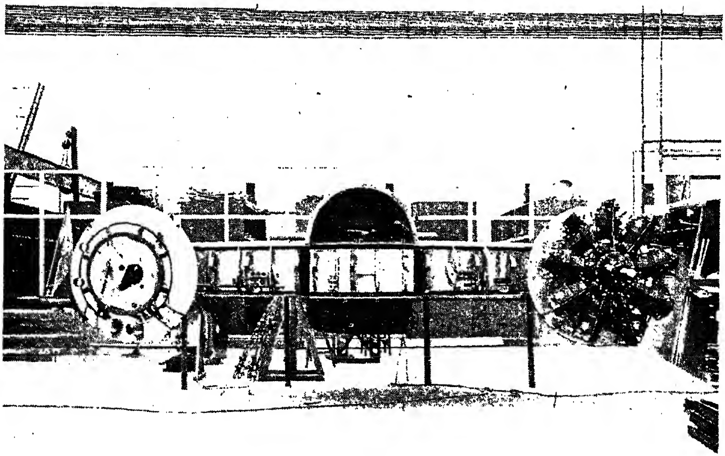


Fig. 1.—THE CENTRE PLANE SECTION OF THE "BRISTOL" BLENHEIM BOMBER.
Showing the rear fuselage in position and one engine mounted.

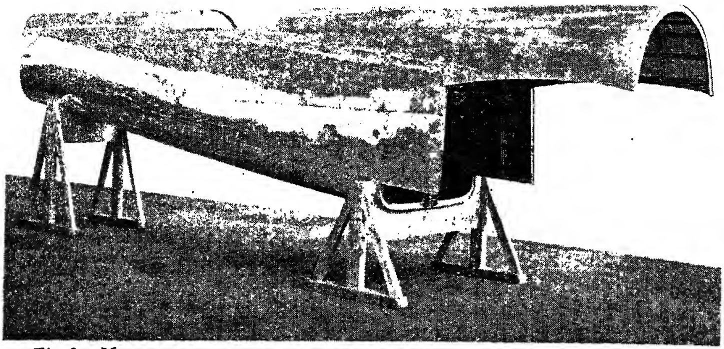


Fig. 2.—MONOCOCQUE STRUCTURE FORMING REAR FUSELAGE OF THE "BRISTOL" BLENHEIM BOMBER.

assembly. With the centre plane in position the work of attaching several components, as detailed below, can proceed simultaneously.

(1) **Rear Portion Fuselage** (see Figs. 2 and 3)

The rear spar of the centre plane carries jig-drilled channel fittings which attach to the vertical faces of formers at the forward end of the rear fuselage. The rear fuselage is brought forward to the centre plane, supported on trestles at its correct height, checked up for alignment of datum in both directions and the bolts are then inserted, securing the two components (see Fig. 4). If root fillets are included in the design between centre plane and rear fuselage they are now secured in place.

(2) **Front Portion Fuselage** (see Fig. 5)

This component is now brought up into place, supported on trestles and correctly set up as shown in Fig. 4. In addition to the attachment on to the front spar channels (see Fig. 1) there is also the strap plate attachment round the upper portion, as illustrated in Figs. 2 and 5.

(3) **Tail Portion Group**

The stern frame, tail plane, fin and tail wheel under group (*c*) are assembled prior to bringing up to the rear fuselage. Following from the detailed description of the components the order of assembly is as follows :

With the stern frame set up on a suitable fixture, representing the rear former of the rear fuselage, and a cradle for the rear part, the tail plane is bolted in position and the angles attached to the stern frame by

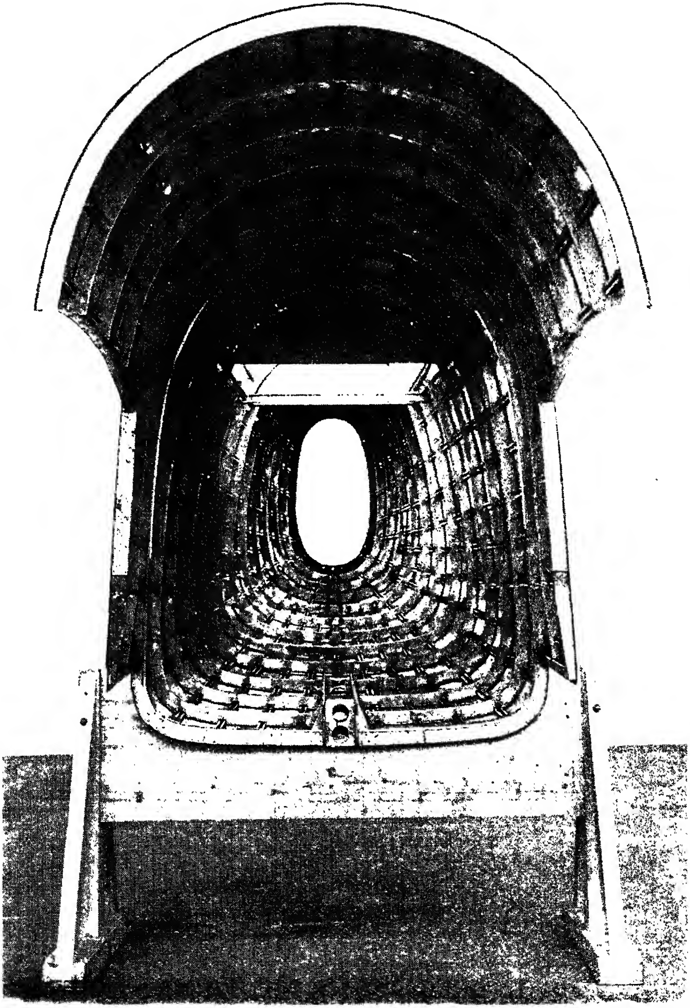


Fig. 3.—THE MONOCOCQUE FUSELAGE OF THE "BRISTOL" BLENHEIM BOMBER, SHOWING REAR SECTION WITHOUT "NOSE."

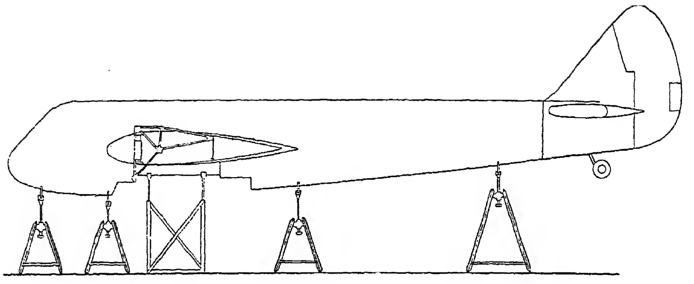


Fig. 4.—CENTRE PLANE, FUSELAGE AND TAIL PORTION ASSEMBLY.

screws. The fin is now fixed on by its bolts and setscrews to the stern frame and tail plane.

The fitting of the tail wheel now completes this group, and the whole is now ready for offering up to the rear fuselage. With the above group secured to the rear fuselage in its true position the bolting up of the strap attachment plate completes the operation.

The rudder and elevators are now placed in position, the hinge bolts fitted and the rear end assembly is completed. As for all other components, an inspection check for correct setting of the various items will be carried out, but in view of the fact that all attachment points are jig-drilled, no cases of inaccurate assembly should arise outside the specified limits allowed.

(4) Engine Mounting, Engine and Controls

During the period assemblies (1), (2) and (3) are proceeding, the items under this group will be handled. The rear portion of the engine mounting, *i.e.*, the nacelle structure, is firstly placed in position and bolted up. The forward portion carrying the engine mounting ring is built up on a separate stand upon which all the installation details are fitted, including the fireproof bulkhead and also the front part of the engine cowling and its structure.

The whole unit is now brought up to the centre plane and connected at its four main fixing points. The next operation consists of securing the engine in position on the mounting ring and following this the exhaust system is secured in place.

Fuel tanks, oil tanks and oil coolers, together with their air pipes, are next assembled and also various other items which are connected directly to the engine. With the engine and main items fitted, all the pipe lines can be coupled up, the electrical connections to the engine made and the engine and fuel tank controls connected up, including all the points between front fuselage and centre plane, in addition to the engine end.

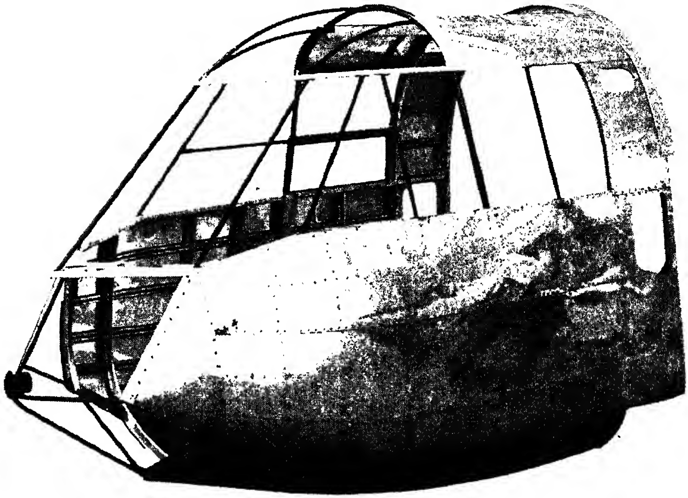


Fig. 5.—THE FRONT FUSELAGE OF THE "BRISTOL" BLENHEIM BOMBER.

It is of interest to note, that for a modern twin-engined aeroplane, the mechanically operated engine controls stationed in the pilot's cockpit may consist of the following :—

Carburetter throttle control—port and starboard engine.			
Carburetter mixture control	,,	,,	,,
Air intake shutter control	,,	,,	,,
Slow running cut-out	,,	,,	,,
Airscrew pitch control	,,	,,	,,

(5) Flying Control Assemblies

During the period the centre plane is in the assembly jig a large proportion of these controls can be coupled up to their respective points, viz., (*a*) rudder controls from rudder bar to rudder ; (*b*) elevator controls from the layshaft in the front fuselage to the rear layshaft and elevator lever ; (*c*) tail wheel mechanical control (if fitted) connected from the undercarriage through to the tail wheel operating lever ; (*d*) aileron controls for those parts in the centre plane and front fuselage.

(6) Undercarriage Retracting Mechanism and Brake Gear

Any connections between the front fuselage and centre plane are now made off at this stage, and if the systems are hydraulic this will consist of making up the pipe line junctions.

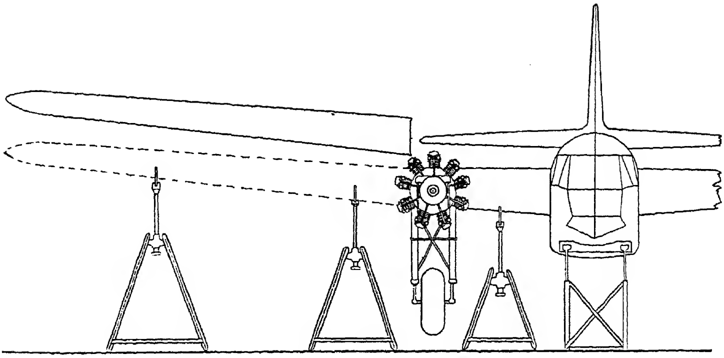


Fig. 6.—OUTER PLANE AND UNDERCARRIAGE ASSEMBLY.

(7) **Electrical Services**

The junction points on the electrical services between the various components will be made on terminal blocks, and the wiring can be connected up at this stage, but will not be checked through until the aeroplane is completely assembled.

FINAL ASSEMBLY

The group assembled up to the stage described is now removed bodily from the jig and transported by a special travelling crane to a new position on the erection hall floor for completion of the outstanding work. The fuselage and centre plane, now assembled together, are set up on trestles (see Figs. 4 and 6) to give correct rigging position, and erection will proceed as follows :—

(1) **Undercarriage—Port and Starboard**

These components will be connected up at the attachment points, and if retractable, all points on the operating system made off including those for the tail wheel. The operation of retracting will be checked up during group (3) tests below to ensure all mechanisms function correctly and that the stipulated clearances between fixed and moving parts are attained.

(2) **Outer Planes**

These components are now offered up in position (see Fig. 6) and bolted up at the inner end fittings attaching them to the centre plane.

(3) **Control Surfaces** consisting of centre and outer plane flaps and also the ailerons are now attached at their respective stations and the

control couplings for the flaps fitted. The check for correct functioning of the hydraulic system for the flaps will be made at the same time as the undercarriage retraction tests are in hand.

(4) **Aileron Controls** are now coupled up at the junction of the centre and outer planes and also at the levers fitted direct on the ailerons.

(5) **Electrical Connections** are now made off at the junction points at the root of the outer planes, and if landing lamps are fitted in the leading edge of the outer planes the mechanism for controlling beam pitch is coupled up.

(6) **Instruments** which, on account of their liability to damage, have been left out in the earlier stages of assembly, are now fitted to complete the installation.

(7) The **Airscrews** are fitted in place on the engines and locked up.

Now all components are assembled into position with the exception of the engine cowlings, the work of correctly adjusting the flying controls to give the specified angular movements of the surfaces can be carried out. In addition, the electrical services will now be checked for continuity of the various systems of current supply to lamps, batteries, etc. A rigging check will next be carried out to verify that the aeroplane conforms to the dimensions and angles specified on the rigging chart.

When the aeroplane is released by the inspection group as correct to drawing specification it is passed forward to the flight department.

TUNING UP AND PREPARATION FOR FLIGHT CHECK

Before carrying out the acceptance test flight the following items are checked over:—

(1) Fuel System

The system is checked over for joint tightness on the pipe lines and also to confirm that the tanks are free from leaks. A fuel flow test is next carried out by breaking a connection close to the carburetter and taking the rate of flow which should meet a specified minimum figure for a given hydraulic head. In addition to the above the fuel level gauges are operated to check for accuracy of reading.

(2) Oil System

The pipe lines are checked for joint tightness and the tanks for soundness.

(3) Engine Controls

The setting and operation of the throttle and mixture controls are

now finally adjusted to give correct travel and synchronisation and also to ensure there is no lag in the system due to backlash at the joints.

(4) Engine Running

The sparking plugs are now fitted and the aeroplane taken out for engine running and final tuning. With this test giving satisfactory results, the engine cowling is finally assembled.

(5) Compass Swinging

The aeroplane is now taken on to the compass course and the compass checked and corrected as necessary.

The aeroplane is now complete and, after fuel and oil are placed in the tanks, is ready to carry out acceptance flights prior to delivery.

DEVELOPMENT, CONSTRUCTION AND USE OF AERODROME GROUND EQUIPMENT

By Wing-Commander G. W. Williamson, O.B.E., M.C., M.Inst.C.E., M.I.Mech.E., M.I.E.E.

When aeroplanes were first used, in comparatively small numbers, the arrangements made for their handling and maintenance were surprisingly primitive. Aeroplanes might arrive at landing grounds where there was no accommodation for them under cover; if an aerodrome were of sufficient importance to possess a permanent hangar, heavy doors would have to be moved back and forth by hand whenever aeroplanes were taken out or put away.

The aeroplanes were manhandled; to move an aeroplane out of its shed required the services of five or more men, the larger proportion staggering along holding the tail skid off the ground, while a more fortunate few pulled or pushed in order to propel it. Aeroplanes of those days were marked along the fuselage to show the place at which handling parties should catch hold in order to raise the tail skid from the ground, each such point being lettered "Lift Here."

On getting the aeroplane out on the tarmac, the next procedure was filling up with fuel. All fuel was in 2-gallon cans and most tanks were between the dashboard or instrument panel and the engine. One mechanic would stand on the wing and pour the fuel into a funnel stuck casually into the tank opening, while a handling party would pass him one can at a time from a stock carried on a trolley made up of a pair of wheels from some crashed aeroplane.

Oiling and greasing were carried out with a similar waste of labour and time; tyres were pumped up by means of a large bicycle pump, if no foot pump was available. It should however be recollected that aeroplane tyres of those days were similar to those of motor cars, and took no more pumping up. When testing or tuning the aeroplane was necessary, some form of trestle was knocked up in the carpenter's shop; if it did not fit any particular type, the aeroplane was supported in flying position by means of a precarious pile of packing pieces placed on top of some odd trestle or on two or three boxes.

Special ladders could be purchased at the local ironmonger's, and as aeroplanes were all much of a size except for the Handley Page twin-engined aeroplanes, it was not difficult, with stock sizes of folding steps, to reach the upper surface of the top wing.

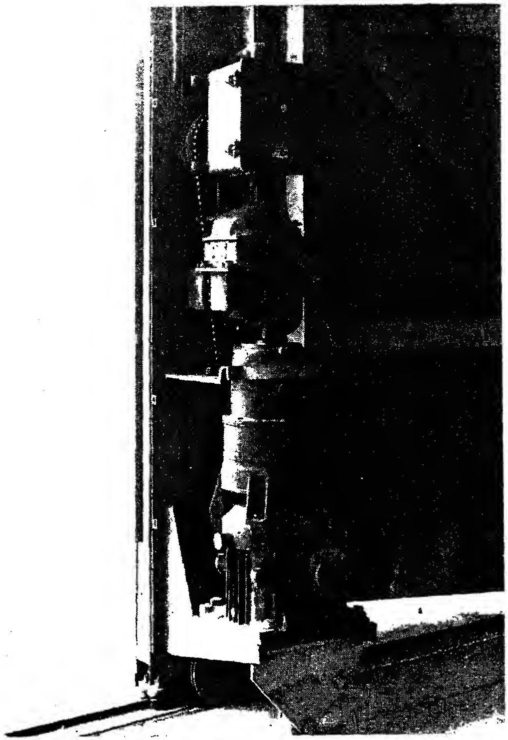


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Fig. 1.—DETAILS OF WINDING GEAR.

If it became necessary to remove an engine, the operation was carried out by block and tackle slung from the trusses of some permanent building or from sheer-legs contrived from scaffolding poles purchased from some builder's yard. The engine, when removed from the aeroplane, was placed on an engine stand made of wood and looking like a pair of clumsy parallel bars.

No one thought of weighing or even of estimating the load carried by an aeroplane; sometimes pilots went off in an aeroplane which could only just stagger over the hedge at the end of the aerodrome; or on the other hand they left valuable equipment behind them for fear that taking it might make the aeroplane feel soggy.

It is true that in those days there was some form of fire tender, usually some old vehicle painted red and equipped with a few aged and ineffective fire extinguishers. It was rather later that rules were made in regard to a periodical testing of extinguishers which had not yet been used; it was later still before it was realised that a fire tender might have to proceed over soft or muddy ground and might fail to reach a burning aeroplane if held up by the condition of the surface of the aerodrome.

The direction of wind was indicated then as now by a wind sleeve, in those days of so small a size as to be almost invisible from the air. It was supplemented by a T made of linen fabric tacked to a wooden frame

and it was the duty of some person to go out to the middle of the aerodrome and alter the T whenever the wind changed. If he forgot, a crash might result; but then aeroplanes were so lightly loaded and so collapsible that many crashes occurred with but small injury to the pilot.

Economy of Mechanical Handling

This picture of aerodrome conditions before 1914 is necessary to show the manner in which handling equipment for aeroplanes has developed and improved; and to indicate the points at which there is so considerable a saving of time and money as to make the use of up-to-date aerodrome equipment an economy.

At airports, where a number of very large aeroplanes may have to be handled and serviced, a large permanent ground staff would be necessary under the old conditions. The use of mechanical devices and items of equipment for maintenance purposes results in a huge saving of money; equipment of the types dealt with in this article is therefore found at every airport.

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Fig. 2.—WINDING GEAR COVERED, SHOWING PUSH-BUTTON CONTROL.

During the war 1914–18, large staffs of airmen were available for handling and maintenance on every aerodrome; it was not until peace conditions reduced aerodrome ground staffs to a minimum that improved methods of handling and servicing were developed. Nowadays, the handling of aeroplanes on Royal Air Force aerodromes is not behind that of any civil airport in speed and efficiency. These two characteristics are an essential on aerodromes used by fighter squadrons. It may be vitally necessary for such aeroplanes to take the air almost immediately on receiving news of the attack of an enemy squadron; seconds gained by mechanical handling would be priceless if more time were therefore obtained in which fighters could gain height favourable for attack.

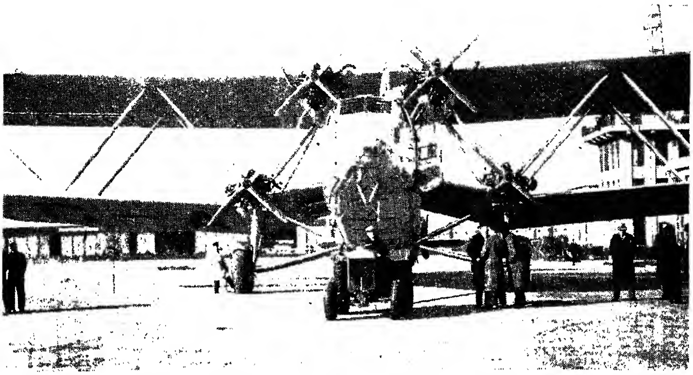
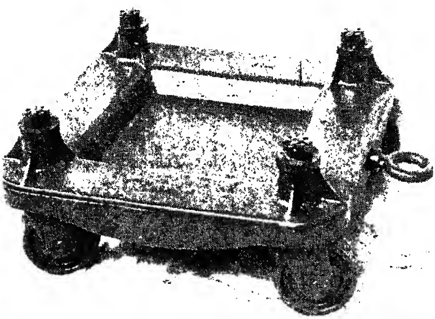


Fig. 3.—FORD AERODROME TRACTOR AT CROYDON.

The weather in this country is not always favourable for flying, especially for flying training. Both at Royal Air Force stations and at civil flying training schools it may be essential to fit long hours of flying into any favourable day in summer; it has been the experience of personnel connected with the civil schools that time saved by mechanical handling and maintenance is amply repaid in increased flying hours.



[*Brown Bros. Ltd.*

Fig. 4.—ERN-LAKE TROLLEY FOR TAIL SKID.

Hangar Doors

Reference has been made previously to the difficulty and delay of opening the large doors fitted to the permanent hangars. If there were not a sufficient aerodrome staff available, doors simply could not be opened at all; when it became necessary for a single

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Fig. 5.—ESAVIAN DOORS AT SPEKE AERODROME, LIVERPOOL.

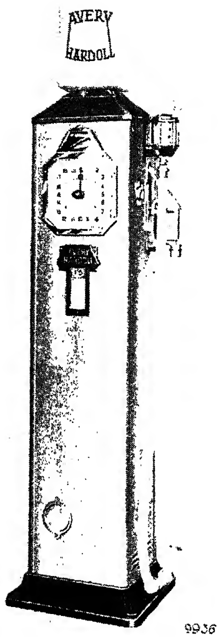


Fig. 6.—METERING FUEL PUMP.

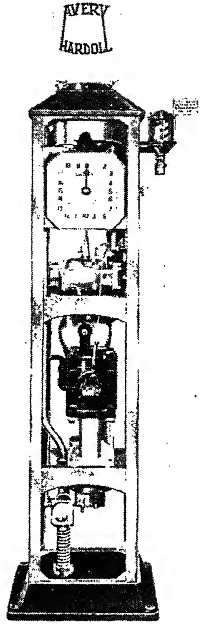


Fig. 7.—INTERIOR OF METERING PUMP.

aeroplane to leave at dawn, as many as twenty men had to be available to get it out. Nowadays, one man could open the doors of the largest hangar. Fig. 5 shows Esavian doors similar to those supplied to R.A.F. stations at home and overseas and installed at Speke Aerodrome, Liverpool. One set of these doors is no less than 199 ft. long and 35 ft. in height. It will be observed that these large doors collapse sideways like the folds of a concertina or camera. If the buttress is built out beyond each side wall of the hangar, these doors can be made so as to leave an opening the full width of the hangar. If provision is not made on these lines, the space taken up at each side of the hangar by collapsed doors is approximately 11 ft.

Not alone are doors of this pattern specified on account of the speed at which they can be opened, but in exposed positions they have proved to be the only ones which would stand up to gales. They are staggered in a way which enables them to present a greater resistance to the wind than any other type.

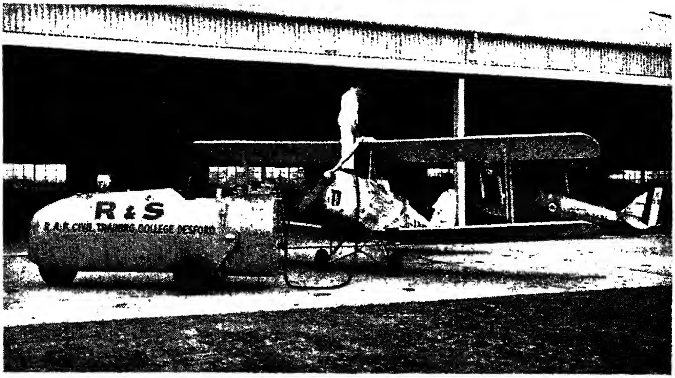
The illustration of the outside of the doors shows that the leaves are hinged in pairs ; each leaf is attached to a sliding upright resting upon a large bottom runner fitted with ball bearings which run on a metal track. These bottom runners carry the entire weight of the structure ; at the top each pair of leaves is provided with a twin top guide and ball bearings. As this wheel in each case is no more than a guide, it is not necessary to strengthen the lintel. The shaft of the wheel of each top

[*Thompson Bros. Ltd.*

Fig. 8.—LARGE REFUELLING UNIT.

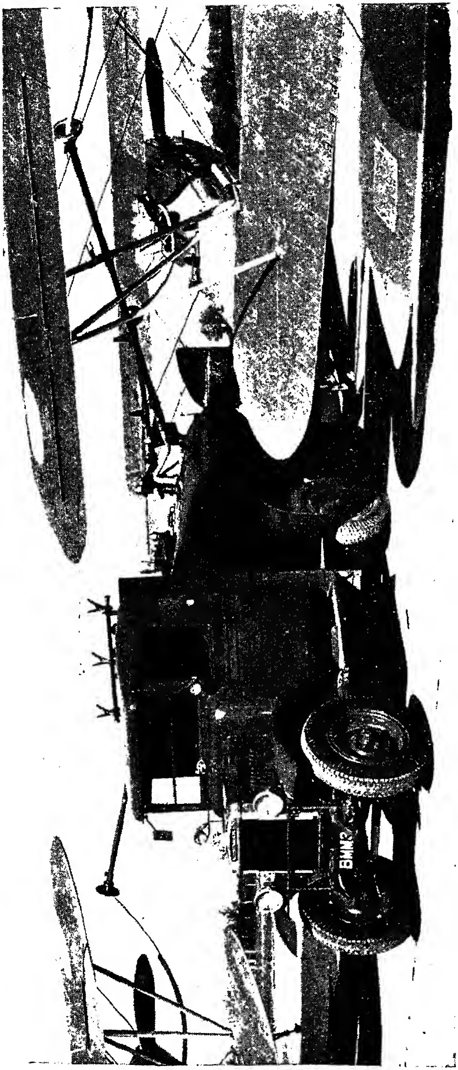
guide is vertical, so that the wheel itself lies horizontal and runs between two light steel angle guide or brackets.

Even large doors of this type can be handled by one man by means of a manually operated winding gear, but it is much quicker if electrical winding gear is provided ; in this case, the operation of opening or closing the doors illustrated occupies approximately 40 seconds. The motor winding gear is illustrated at Fig. 1 without its cover ; it is provided with an adjustment for hand winding in case of the failure of the current.



[*Thompson Bros. Ltd.*

Fig. 9.—SCHOOL TYPE REFUELLING



[Zwicky Ltd.

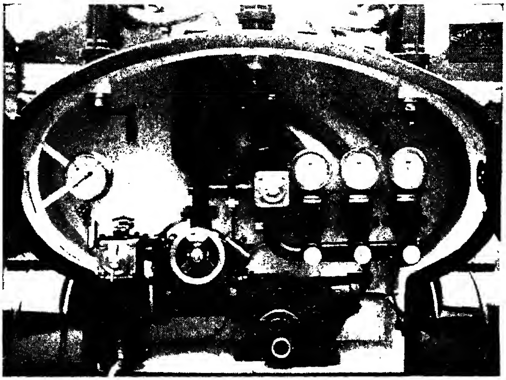
Fig. 10.—THREE-BOOM REFUELLING UNIT.

When in use the winding gear is covered and then appears as illustrated in Fig. 2. A 3-h.p. motor is required; this moves the doors in either direction at a speed of 55 ft. per minute. As will be seen from Fig. 2, the motor has push-button control and is completed with a limit switch to prevent overrunning when extended or folded. The doors are fitted with switches which cut off the current, making it impossible to open them until the lever fasteners are uncoupled.

Whether hand or electrically operated, the doors are actuated by the winding gear of endless cable type, the winch being carried in the centre meeting sliding upright. Cable adjustments are provided at either end of the winding gear, and can easily be operated by one man.

Equipment for Handling Aeroplanes

When the mech-



[*Zwicky Ltd.*

Fig. 11.—INTERIOR OF REAR PUMP COMPARTMENT.

anically actuated doors have been opened, the next task is the moving out or in of the aeroplane; while all aeroplanes in the past were moved entirely by human labour, the largest aeroplanes of to-day make mechanical handling an absolute necessity.

Visitors to Croydon will have noticed the ease with which a small tractor and one man can manœuvre the large Handley Page aeroplanes. Fig. 3 shows one of these tractors in use. Although most of the movement of aeroplanes will be carried out only upon concrete aprons, the possibility may arise of an aeroplane sinking into a soft spot on the aerodrome, in which case caterpillar treads would be required to prevent the tractor digging itself in as well.

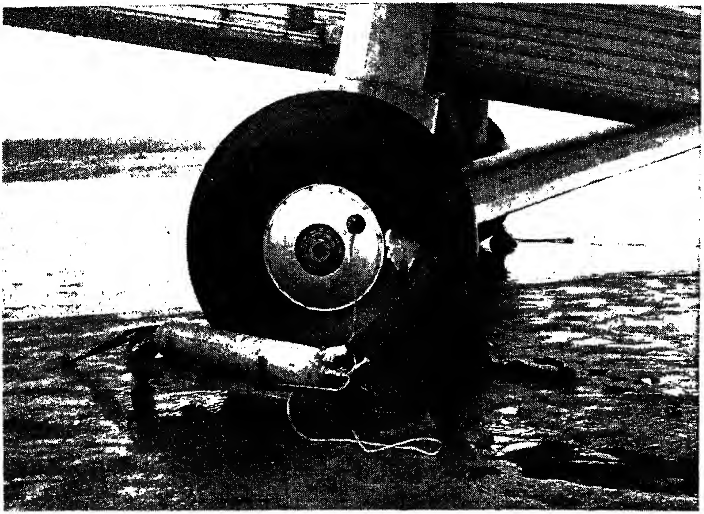
The tractor illustrated is produced at the works of the Ford Motor Company Ltd., at Dagenham. Its engine is of the 4-cylinder type, normally intended to run on petrol.

The specification of this aerodrome tractor corresponds to standard industrial vehicle equipment; but where it is quite certain that the tractor will only be employed in handling aeroplanes on concrete aprons, the expensive caterpillar tracks need not be fitted.

The tractor is provided with an automatic coupling which permits connection to a standard form of trailer without the necessity of the driver leaving his seat; for aeroplane purposes, however, towing is usually carried out by cables.

Where shed space is limited, it may be difficult to pack aeroplanes in so as to use fully the interior of the hangar; for some years the R.A.F. as well as other operators have used a device styled side-tracking skates.

Each set consists of a pair of very small trolleys, with wheels only a few inches in diameter. The wheels of the aeroplane are manhandled on to these small trolleys, although if a tractor is available the operation will be even more easily performed. Once the wheels are on the trolleys the whole aeroplane can be moved sideways into positions difficult to fill with or without mechanical handling; the wheels are swivelling so that



[*British Oxygen Co. Ltd.*

Fig. 12.—PUMPING UP

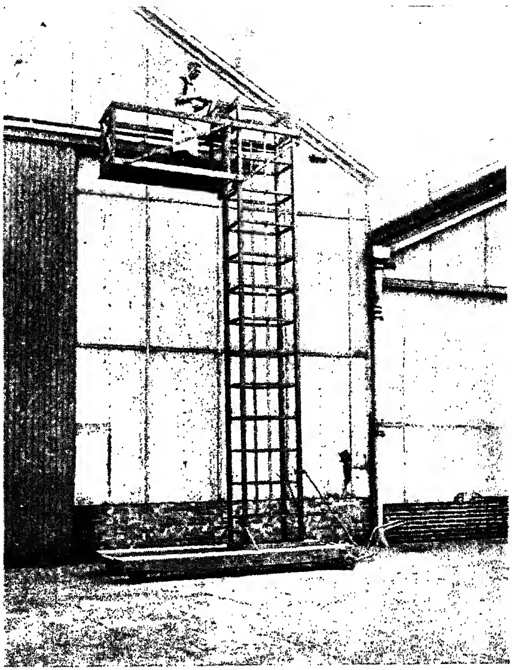
the aeroplane can be moved backwards, forwards or sideways at any angle as required.

Before the days of tail wheels, the heavy load on the tail skid of any large aeroplane made handling a difficult matter; in flying schools or anywhere else not using aeroplanes provided with tail wheels, a similar small trolley can be used for the tail skid. This is illustrated in Fig. 4. Alternatively, a tail trolley with a long handle can be used; but this has its greatest use on aerodromes where labour is limited and the aeroplanes are not very large.

Refuelling

The days are gone when the fuel store of any aerodrome consists of a few hundred gallons in 2-gallon cans. All aerodromes possess the usual underground tanks, connected to metering pumps from which refuelling vehicles can be filled.

Every aerodrome therefore possesses at least two or three such pumps, depending on the number of types of fuel required to be issued. Figs. 6 and 7 show the internal details of a standard type of pump; but it will not be necessary for aerodrome staffs to concern themselves with the internal working of this type of pump which is usually looked after by the supplier of the fuel.



[*Ransome, Sims & Jeffries Ltd.*

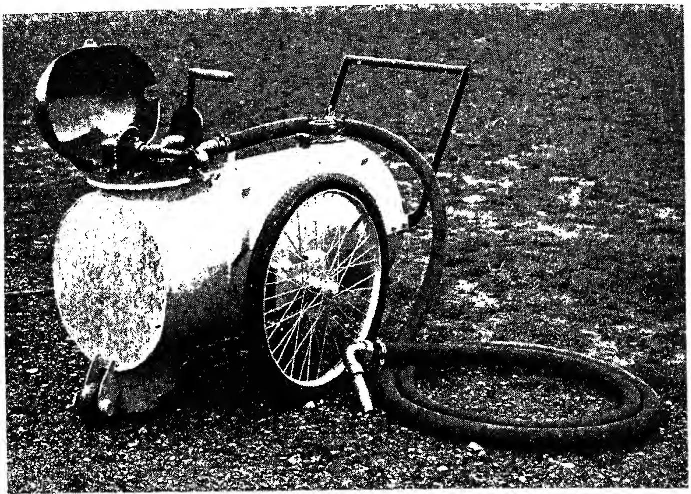
Fig. 13.—TOWER LADDER.

Four steel angle uprights are fixed rigidly at their lower ends to the base casting and at their upper ends to the cast canopy. Steel angles are welded to the uprights at suitable points for carrying the discharge register, meter supporting plate and motor bracket. It is due to this strong rigid framework, and to the absence of vibration, that a light foundation is possible and grouting-in is avoided. The steel framework is rust-proofed prior to painting.

The whole mechanism is enclosed within a rectangular steel casing comprising four panels, which are fixed by means of screws to the uprights of the frame. The removal of the casing panels for servicing does not involve any disturbance of the mechanism except the zeroising knob, which must be removed to allow the chart glass to pass.

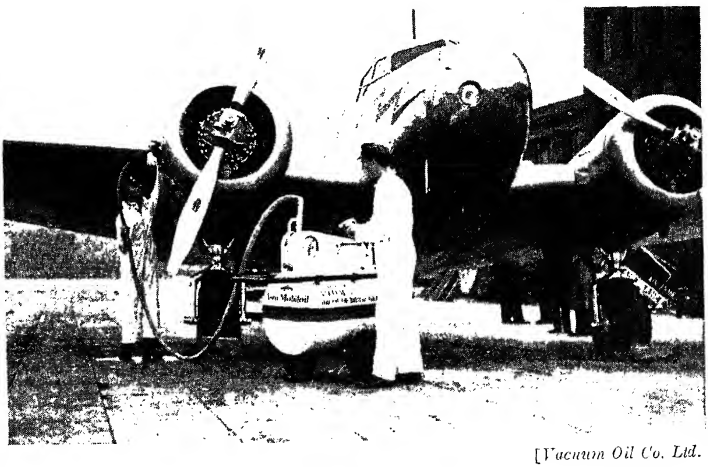
The discharge register is a totally enclosed unit providing two large dials at either side of the equipment, the chart glasses being contained in the casing panels. All spirit passed through the meter is indicated on both dials by 1-gallon and 20-gallon pointers. A zeroising knob permits the reversal to zero of all four pointers before beginning a new delivery.

Aeroplanes can of course be brought on to the tarmac for refuelling directly from a meter pump such as this ; but this involves considerable delay and congestion of the concrete aprons and the modern practice is to take fuel to the aeroplanes in mobile units, thus saving not only many man-hours, but much running of the aeroplane engines.



[Thompson Bros. Ltd.

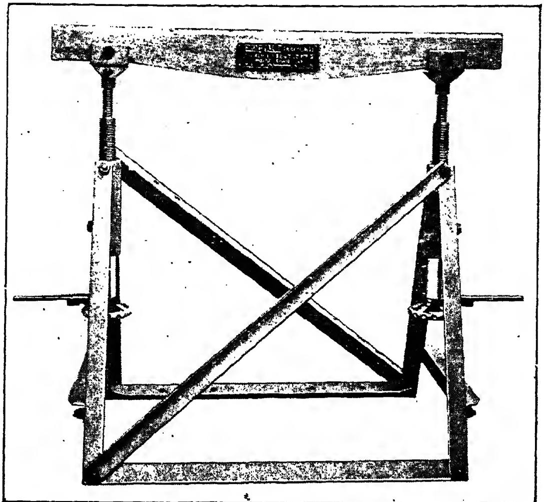
Fig. 14.—HAND-OPERATED REFUELLING UNIT.



[Vacuum Oil Co. Ltd.

Fig. 15.—REFILLING OIL TANKS.

This policy has resulted in the production of a considerable range of refuelling units of various sizes. One of the largest in operation is shown in Fig. 8; while a small and speedy unit specially developed for civil flying training schools is shown in Fig. 9. A few brief details of each of these two units will be sufficient to show the trend of modern construction. The school type of unit carries a total of 450 gallons with compartments for one, two or three grades of fuel. The output is 20 gallons per minute against a 20-ft. head; the unit is driven by a 8-h.p. engine fitted with a self-starter. The chassis has a 3-speed and reverse gear-box, with an auxiliary gear for the pump.



[Brown Bros. Ltd.

Fig. 16.—ERN-LAKE WING TRESTLE.

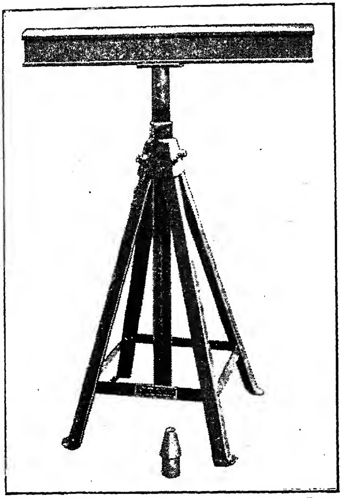
The larger sizes of refuelling unit are fitted not only with two hoses, but one has been produced for simultaneous filling of three aeroplanes standing in formation. The maximum capacity for such a unit may be as much as 1,000 gallons and the pumping rate reaches 100 gallons per minute. This three-boom vehicle is illustrated in Figs. 10 and 11.

At the opposite end of the scale is the hand-operated set illustrated in Fig. 14.

Oil Supply

Auxiliary equipment for oil supply could be fitted to such vehicles if required; alternatively, oil supply arrangements can be independently made, in which case a small trolley carrying an oil tank and pump could be brought close to the aeroplane, as illustrated in Fig. 15.

The unit illustrated comprises a 50-gallon portable oil tank and pump designed to facilitate rapid and efficient servicing of commercial aeroplanes with clean lubricating oil. The arrangement has been evolved



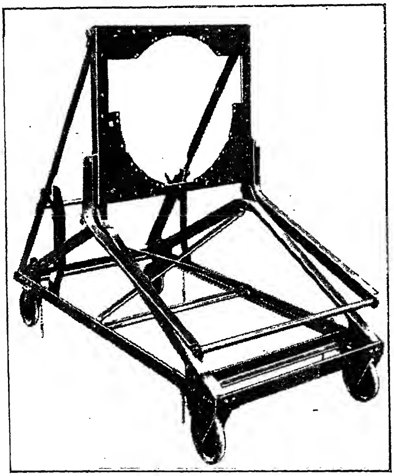
[*Brown Bros. Ltd.*

Fig. 17.—ERN-LAKE TAIL TRESTLE.

to provide a simple and practical scheme for dispensing oil in measured quantities, avoiding the use of oil measuring and eliminating possible contamination.

A cylindrical tank is mounted on a tubular steel axle with two 16 in. × 4 in. rubber-tyred disc wheels running on ball bearings to give the least resistance to rolling with a full tank over rough ground, and a central baffle plate prevents oil surge.

Steel skid plates are fitted at either end to steady the tank when pumping, and a hand rail encircles the tank top, this being positioned suitably at a predetermined height to assist manœuvrability. The hose is placed inside the hand-rail when not in use and the anti-drip nozzle is retained in a suitable pocket over the tank filler.

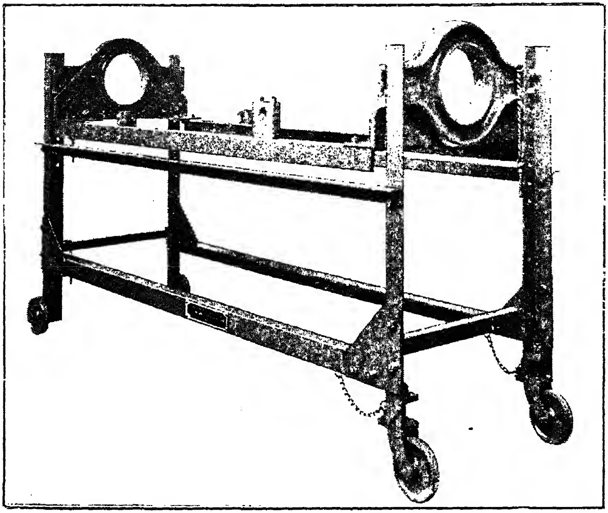


[*Brown Bros. Ltd.*

18.—ERN-LAKE STAND FOR RADIAL ENGINE.

A reversible type full rotary pump delivers the oil at a rate of 2 to 3 gallons per minute through a "Victory-Five" precision meter, calibrated in pints and 15 ft. of 1-in. bore oil-resisting hose is provided with a spring-controlled anti-drip nozzle at the end. As the discharge pipe from the tank is 5 ft. from the ground, oil tanks 18 ft. above the ground can be filled. A spare length of hose is available for attachment if required.

Reversing the action of the pump, and by moving a lever link mechanism, the operator is able to refill the



[*Brown Bros. Ltd.*

Fig. 19.—Ern-lake stand for in-line engine.

tank from a steel barrel or bulk tank supply, as a separate pipe and hose is supplied for this purpose. The oil is filtered before entering the tank and again on discharge.

A large filling hole and filter is also available for separate filling if desired and a dipstick shows the oil level. The tank and pump can be locked against unauthorised use. A hood covers the pump and reversing mechanism and provides a clean exterior. One of the latest British Airways Lockheed Electras is seen taking supplies of aero mobiloil at Croydon. Painted white with the distinguishing red and green colour bands, the unit presents a very attractive, workmanlike job.

Pumping up Tyres

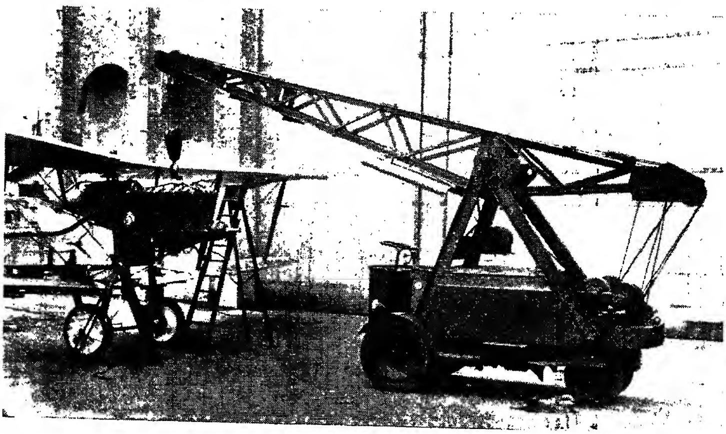
The large tyres of modern passenger-carrying aeroplanes can be pumped up from cylinders, as illustrated in Fig. 12. Another method is to have a portable air compressor and receiver mounted upon a small trolley; this method is frequently used on busy airports.

Starting

At one time, no aerodrome could be considered as completely equipped unless it possessed an engine starter of the type invented by the late Captain B. C. Hucks; it consisted of a chassis in which the engine could

[*Messrs. Peto and Radford.*

Fig. 20.—ENGINE STARTING BY PORTABLE BATTERY.



[*Ransome & Rapier Ltd.*

Fig. 21.—MOBILE PETROL-ELECTRIC CRANE.

be coupled to a vertical shaft geared to an adjustable horizontal one with a bar which could be made to engage with two claws on the airscrew.

Practically all aeroplanes now have independent starting, on similar lines to that of the modern motor-car engines. In this country a very large proportion of aeroplanes have electrical starters; but elsewhere inertia starters or those operated by compressed air are in the majority. Small aeroplanes in this country usually have starting handles in the side of the engine cowling; this obviates the necessity of pulling round the airscrew by hand.

Electrical engine starting puts a very considerable strain upon the batteries of the aeroplane, and uses current which might later on be urgently required for other purposes. As practically all engine starting is done at aerodromes, the ground starting trolley has been devised to save the batteries of the aeroplane.

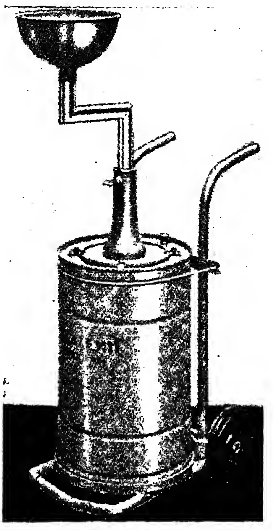


Fig. 22.—TECALEMIT "AERO-DRAIN."

The trolley is illustrated in action in Fig. 20. The trolley itself consists of a stoutly built oak body with hinged lid, the outside of the body being painted with weather-resisting enamel of any desired colour and the inside with acid-resisting paint. The body is firmly mounted on a pair of strong metal axles fitted with pneumatic rubber-tyred wheels, the front axle incorporating a robust metal turntable. The usual pivoted type of handle is provided for moving the trolley from

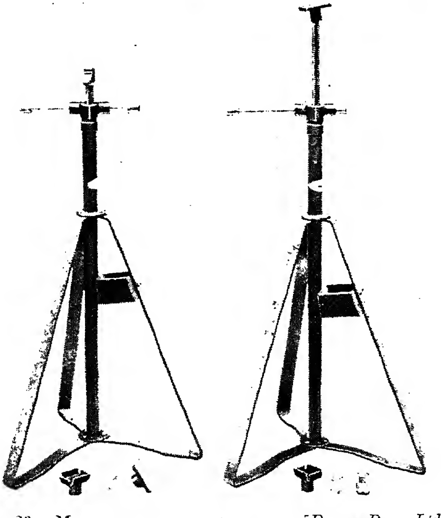


Fig. 23.—MODERN AIRCRAFT JACKS. [*Brown Bros. Ltd.*

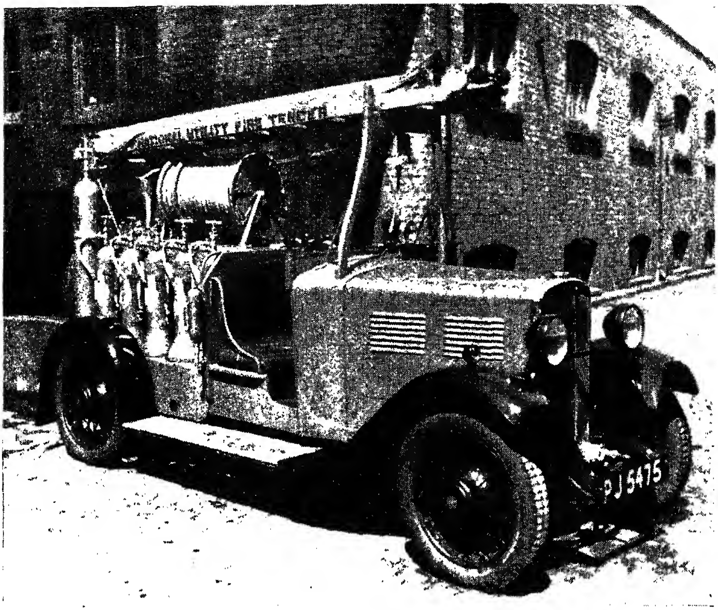


Fig. 24.—MOBILE UNIT ON STANDARD "BIG NINE" CHASSIS.

place to place. Releasing the handle causes two spring-loaded brake shoes to come into operation against the rear wheels, preventing any unwanted movement of the trolley.

The trolley body is internally subdivided into two sections by means of a partition. The rear section houses two specially constructed high-capacity Dagenite starter batteries connected in series to give 12 volts; the front section is fitted with a hinged drop-front, to which are secured four iron brackets and a clip in which the rubber-covered cable necessary to connect the batteries to the plug on the aeroplane is coiled when not actually in use. The whole of the inside of the trolley body is protected by the overlapping hinged lid.

A two-pin plug socket is mounted on the front of the inter-partition, the socket being connected by heavy rubber-covered cables to the main positive and negative terminals of the batteries. To this socket the starter cable must be connected by means of a two-pin plug. The arrangement of the cable brackets inside the front section is such that the drop-front cannot be closed until the two-pin plug has been withdrawn from the socket mounted on the inter-partition, thus causing the cable to become

Fig. 25.—BELL'S ASBESTOS SUIT.

Fig. 26.—BELL'S ASBESTOS SUIT. Showing top half of suit removed.

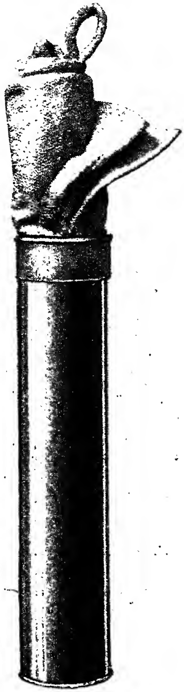
" dead " and preventing any risk of the pins on the plug at the other end of the cable from becoming short-circuited when the trolley is not in use.

A strong vertical batten has been fixed externally to the rear end of the trolley, to which clips can be screwed to accommodate any preferred type of fire extinguisher.

The capacity of this small unit is considerable; if engines will not start after being run on high speed for 10 seconds each, no less than 500 discharges of approximately 100 amperes can be obtained, provided an interval elapses of at least one minute between each discharge.

Servicing of Aeroplanes

With the increasing size of aeroplanes a considerable range of equipment has been developed which enables the servicing of aeroplanes to



[*General Fire Appliances Ltd.*

Fig. 27.—ASBESTOS BLANKET IN CONTAINER.

be rapidly and efficiently carried out. One of the most useful items of equipment is a well-known mobile crane, specially designed for handling aeroplanes and aero engines; it is illustrated in Fig. 21. In operation, the very sensitive electric final drive of this type of crane ensures absolute accuracy in the smallest movement, thus obviating risk of damage to mechanism or fabric. Another considerable advantage of this unit is that once an engine has been lifted either from the aerodrome or from the engine stand in stores or workshops, it can be conveyed to its destination and placed in position with no further handling than that necessarily required for the actual installation or setting down.

The principle of these mobile cranes is as follows: an internal combustion engine drives an electric generator, which in turn supplies power to separate motors on each of the motions of the crane. Any motor can be switched into circuit, for either direction of rotation, by moving a control switch to the appropriate position, thus connecting the motor directly to the generator, no relays or resistances being used. Any number of the motors may be switched on or off at the same time with practically no effect on the other motors running. The voltage generated is varied by foot accelerator control of the engine speed, the volts being zero at "ticking over" speed and a maximum at the full speed of the engine.

To start any motion, the engine speed is reduced by releasing the accelerator pedal, and the control switch, for the particular motion desired, is closed. Under these conditions, a very small voltage is applied to the particular motor, probably not sufficient to move it, but by speeding up the generator set a smooth increase in voltage is obtained, up to a value sufficient to release the solenoid brake on the motor in circuit and cause it to rotate against its load.

To increase the speed of the motor, the voltage is still further increased by the accelerator pedal, up to full speed if necessary. If, in addition to the motion already operating, a further motion is required, the accelerator is momentarily released, the further motion or motions switched in, and

the accelerator again depressed. From this it will be seen that the method of operation is very similar to that of a motor car and that if, as is instinctively done in any emergency, the accelerator pedal is released, all motors stop and all load brakes come "on." This is a very important feature.

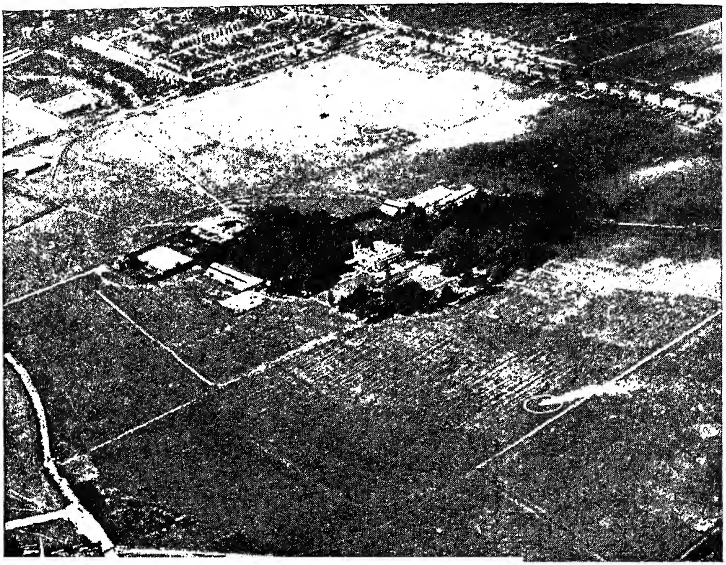
Fig. 28.—Bell's mobile asbestos screen.

Ladders

Especially for aeroplanes, various types of ladders are required for work on the top wings or upper engines. A common form is the swing-back ladder, which will permit, when used in pairs, of planks being run from one to the other in order to support the upper planes of each aeroplane during rigging or maintenance operations.

They require, however, a considerable amount of carrying about; for work on the upper planes or engines where the planes themselves do not require to be supported, a tower ladder has been devised.

Its general appearance is shown in Fig. 13. It consists of a squared



[*General Aircraft Co. Ltd.*

Fig. 29.—SMOKE TRAILS IN USE AT LONDON AIR PARK, HANWORTH.

section structure mounted on a trolley and equipped with a hand-operated platform which can be raised or lowered to any desired height by means of winding gear operated from the platform itself.

Trestles

Trestles are no longer manufactured by a local carpenter every time a new type of aeroplane requires some rigging work to be done. Instead, air stations hold a series of jacking trestles of a type designed at the Air Ministry. One of these jacking trestles is illustrated in Fig. 16, and its height is variable through a range of about 18 in. Another pattern of trestle, more suited for fuselage and tail than as a support for wings, is illustrated in Fig. 17.

Engine Stands

The Air Ministry is also responsible for the latest designs of aero engine stands either suited for in-line engines or radial engines. The radial engine stand shown with its back plate vertical in Fig. 18 can also be tilted until the engine is lying in a horizontal plane, and the engine stand shown in Fig. 19 can be tilted to any angle or until the engine is in the inverted position.

Draining Oil

In any engine overhaul, one of the first jobs is the draining of oil from the crankcase or in an airframe overhaul from the oil tanks. If it is necessary to search round for a receptacle every time tanks and crankcases have to be drained, much time will be wasted. To save time and mess a unit has been specially designed for this purpose, and is illustrated at Fig. 22.

It consists essentially of a tubular frame mounted on two large-diameter hard-rubber wheels, the frame being shaped to form a portable truck with a platform for carrying the drum. The whole is extremely light and easily manœuvrable.

The 10-gallon drum is secured to the frame by means of an encircling strap tightened by a butterfly nut. The strap is capable of being immediately disengaged by loosening the nut a few turns, so that the drum can be lifted from the truck and the oil poured into the bulk filter or waste-oil storage.

The drum carries an extensible and adjustable swan-neck draining tube, at the top of which is situated the bowl with a grid to catch the drain plug. A dipstick showing the contents is provided.

Jacks

Jacks have been specially developed for the first time intended solely for aeroplanes and thus obviating the necessity of continued use of those really intended for motor transport. The tripod base of those illustrated in Fig. 23 stands firm on an uneven surface and gives a surface contact of 40 sq. in., a valuable feature when used on soft ground. A ball thrust takes the weight of the aeroplane and the main screw has a square thread. A micrometer adjustment greatly assists in levelling up aeroplanes or any part of it; and this is especially valuable when a pair of these jacks is used together with a cross-beam so as to form an adjustable trestle.

Fire Equipment

A modern aid to fire fighting is illustrated in Fig. 24. It is designed to fight all types of fire and its scope is far beyond that of any ordinary first-aid fire engine.

The main chemical equipment consists of "Essex" methyl bromide extinguishers, as follows :—

2 1½-gallon extinguishers.
10 ½-gallon extinguishers.
4 No. 3 A.M. type hand-extinguishers.

This equipment is equivalent to more than 128 2-gallon foam machines and covers all cases of fire in which carbon-tetrachloride, foam or carbon dioxide gas are normally used. Repeated tests of methyl bromide have shown it to be more than four times as powerful as other methods.

For the few combustibles which are more cheaply and efficiently extinguished with water, the tender carries 40 gallons of water, which may be applied through a pump at 100 lb. per square inch and provision is also made for working direct from a hydrant wherever possible. A continuous foam installation is also fitted and a 28-ft. extension ladder forms an important addition to the equipment.

The chassis of this fire tender is a Standard "Big Nine." The accessories include a 40-gallon first-aid tank mounted inside the body with 120 ft. of hose on a reel with a shut-off nozzle.

An "F.A." double helical gear pump, driven direct off engine crankshaft, is mounted in front of the radiator and has a working pressure of 100 lb. per square inch, the clutch control being operated from the driver's seat. The hydrant adaptor with gun-metal valves connecting to pump or direct to hose reel is carried complete with hydrant couplings.

A continuous "foam generator" designed for coupling direct to the "first-aid" hose reel is supplied, with four 10-lb. tins of powder and 75 ft. of 1½-in. rubber-lined hose in 25-ft. lengths. When the pump is working at 100 lb. pressure, approximately 7 gallons of water per minute are passed and about 10 lb. of powder are drawn into the stream, while the foam output is about 50 gallons per minute and the jet 35 ft. to 40 ft. in length.

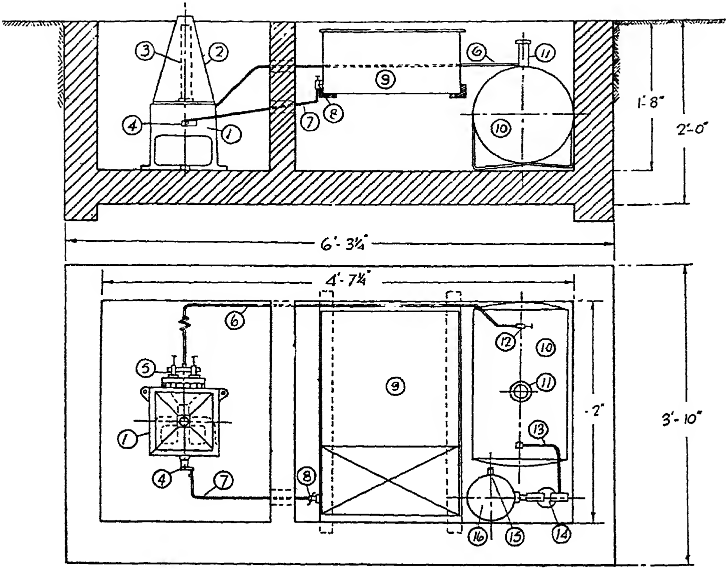
Amongst special devices for rescuing the occupants from a blazing aeroplane, asbestos fire-fighting suits enable the wearers in emergency to remain in a temperature of 1,500° F. for a period of two minutes. The equipment itself will stand up to a blow-lamp flame of 1,600° F. for five minutes before the clothing underneath commences to burn.

Although this suit, complete with helmet, gloves and boots, weighs some 52 lb. (the approximate weight carried by a soldier in marching order), it still allows adequate freedom of movement and as the weight is evenly distributed over the body, does not seriously affect the man's activity. It is illustrated at Fig. 25.

The visor in the helmet is specially designed to give the wearer an excellent field of vision.

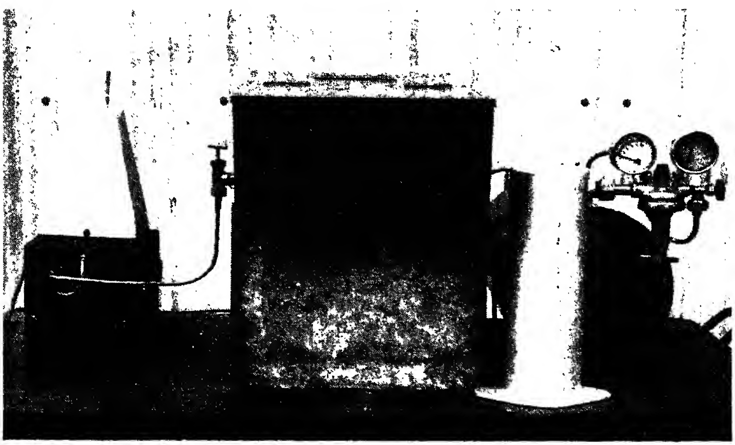
Suits such as these, but made in two pieces so that the wearer is able to keep the lower half on when on normal duty, putting on the upper part only in emergency, now form part of the ordinary protection equipment at each R.A.F. aerodrome throughout the country. Many are also in use at civil aerodromes. Fig. 26 shows the suit in two halves.

In the hangars progress has been made in methods of isolating fires by means of asbestos curtains. There are several types, chief of which is the drop curtain, used to cut off any outbreak of fire from the surrounding aeroplanes or property. These curtains are on rollers and can be dropped by hand immediately a fire is discovered, or if of the automatic type, fall by the action of the heat melting an automatic valve. The advantages of the latter type are obvious, for a fire may not be discovered until it has got a good hold on the building or any aeroplane stored there.



[*General Aircraft Co. Ltd.*

Fig. 30.—SECTION AND PLAN OF SMOKE TRAIL APPARATUS.



[*General Aircraft Co. Ltd.*

Fig. 31.—SMOKE TRAIL APPARATUS.

Similar in use are the mobile fire screens, which can be moved to any part of the airport to screen off flames and isolate the other surrounding property.

A smaller type of screen, for personal use, is the folding asbestos shield, which is extremely useful to firemen using hose pipes, for by holding the shield before them they can approach fierce flames with impunity. There is an aperture in it for the hose, as shown in Fig. 28.

Small outbreaks of fire can be smothered at their source by means of the asbestos fire blanket in sizes up to 6 ft. square. These blankets are of vital importance where there is any danger of clothing catching fire. They also provide adequate protection to anyone who is handling one of them and who has to approach the flames closely before throwing or dropping it. Actually, the blankets always enhance the value of chemical fire extinguishers by the protection they afford to the operator, who is often unable to use the mechanical unit without such protection. The blankets can be used repeatedly and replaced in containers, illustrated at Fig. 27.

Smoke Trail

Finally, no amount of landing tees can provide, from a height, such a clear indication of the way of the wind as the smoke from a fire. In the foreground of Fig. 29 the smoke trails appear to be nearly 200 yards long and clearly show the wind direction even though it would be necessary to search for some time before finding a landing tee or a wind sleeve.

Flush with the aerodrome level, the apparatus causes no obstruction whatever. It is adaptable for flood lighting at night and consumes in one week only 4 gallons of fuel and four of liquid oil.

Its principle of working is as follows: crude oil is fed by gravity to a hot-spot which vaporises the oil. The source of heat is a petrol or paraffin blow-pipe fed from a pressure tank. Pressure is obtained by means of a hand- or foot-pump, or by compressed air. An alternative method of heating is by gas, if the supply is available.

The reference numbers in Fig. 30 indicate the following parts :—

1. Lower furnace.
2. Funnel.
3. Superheater.
4. Oil distributor.
5. Burner.
6. Petrol pipe.
7. Oil pipe.
8. Oil cock.
9. Oil tank.
10. Petrol tank
11. Lid clamp.
12. Petrol cock.
13. Air pipe.
14. Reduction valve.
15. Air valve.
16. Compressed-air bottle.

Operation is extremely simple and consists only of cleaning the burners occasionally, topping up the tanks and maintaining pressure.

THE DEVELOPMENT AND DESIGN OF AIRCRAFT RADIO EQUIPMENT

By A. W. Whistlecroft

THE radio engineer linked up with aviation almost as soon as it reached a practical stage of development.

Marconi engineers were making wireless telegraphy experiments between air and ground at Hendon aerodrome as early as 1912. The first radio telephone transmitter for use in the air was made in 1915 and tested with success at Brooklands Aerodrome, where experimental work was in progress under the supervision of Major C. E. Prince. From this time onward the special requirements of aircraft radio have been given serious attention and great progress has been made.

A Review of the Problems Involved

Before dealing with the radio equipment itself, it may be well to review some of the difficulties which are to be encountered in this special field.

It is essential that the designer of radio equipment intended for use in the air should have a good knowledge of the conditions of service of the apparatus in aircraft. If he has not this knowledge, he may produce apparatus which whilst it is efficient from the wireless point of view, when tested on the bench, is quite unsuitable and even dangerous when installed and used in aircraft. The term " aircraft " of course, covers all types of aeroplanes, flying boats and airships.

Conditions and requirements of service vary considerably for the different classes and also according to whether the aircraft is engaged in civil (commercial or private) flying, or military or naval service.

Noise and Vibration

On some aeroplanes the acoustical noise level of combined engine exhaust, airscrew noise and windage is very high. Vibration can be very bad and will cause a lot of trouble unless suitable precautions are taken to minimise its effects.

Interference from Electrical Circuits

Electrical interference has been, and still is, the cause of much trouble with reception, particularly with the reception of telephony or general short wave working. This trouble is caused by electrical disturbances

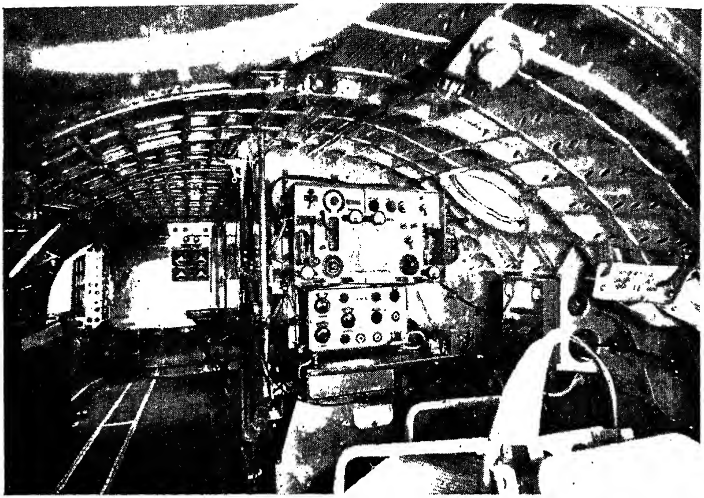


Fig. 1.—MARCONI TYPE AD57A/5872A INSTALLATION IN "C" CLASS EMPIRE FLYING BOAT

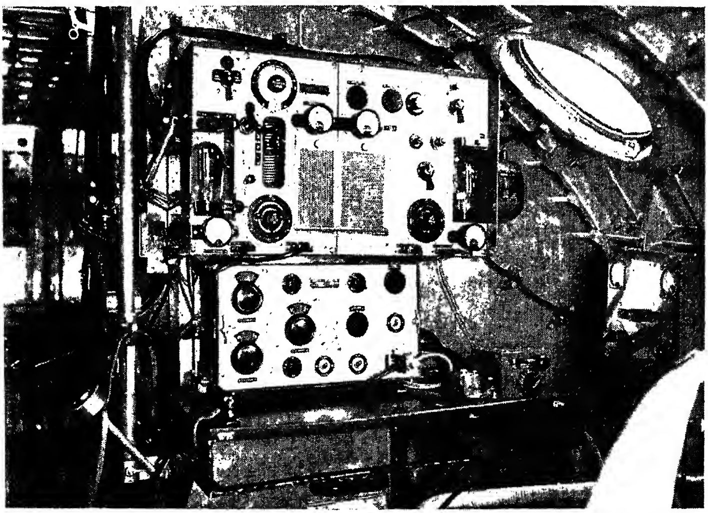


Fig. 2.—CLOSE-UP OF MARCONI INSTALLATION SHOWN IN *Fig.* 1.

radiated from the ignition system of the engine each time a spark occurs at a plug. Sparking at the brushes of electrical generators and voltage regulators of the vibrating contact type also give rise to disturbances which are radiated from the associated wiring. Electrical interference troubles can be overcome by efficient screening and bonding. As applied to the engine, "screening" means that the whole of the ignition system is enclosed within an "earthed" metallic shield. This can be done either by a metal braided covering woven over the individual wires or by enclosing the wires in a metallic conduit. The distributors on the magnetos must also be enclosed within a metal cover and metal screens must be fitted on the sparking plugs. All these metal casings must be electrically bonded and "earthed." This means that they must be connected to the metallic mass of the structure. All bonds must be of low electrical resistance so that high frequency potential gradients cannot build up and so permit radiation.

Interference from charging dynamos and other electric generators can be minimised by keeping brushes and commutators in good condition to prevent sparking. On many modern aeroplanes the complete electrical wiring system is screened, and the screening is properly bonded; this is especially necessary where voltage regulators of the vibrating contact type are used. These regulators should always be enclosed in metal cases provided with suitable junctions for the wiring conduit.

When a screened system is not employed it is often necessary to connect condensers from the generator brushes to earth.

Importance of Bonding

We have referred above to the main metallic mass of the structure as "earth." It is important that this mass shall be electrically bonded throughout.

If there are points of intermittent contact, a harsh grating noise may cause bad interference with reception. Such an instance might occur in an aeroplane of composite construction (combined wood and metal) where bracing wires in a wing are in imperfect connection with the main mass of the fuselage due to a high resistance contact through the fittings at the wing root.

There may, in addition, be wavelength changes and other interferences during transmission. Even in aeroplanes of metal construction this trouble can occur unless bonding is thorough. Efficient bonding is also advisable from the viewpoint of safety. If a portion of the aeroplane is isolated by high electrical resistance from the main mass, it is possible for charges of atmospheric electricity to build up until the potential is sufficient for a spark to jump to the adjacent mass, and in certain circumstances this could be dangerous. The same effect could occur if a powerful transmitter was operated in the aeroplane. Rubber joints in oil or fuel pipes should always be bonded across from metal to metal.

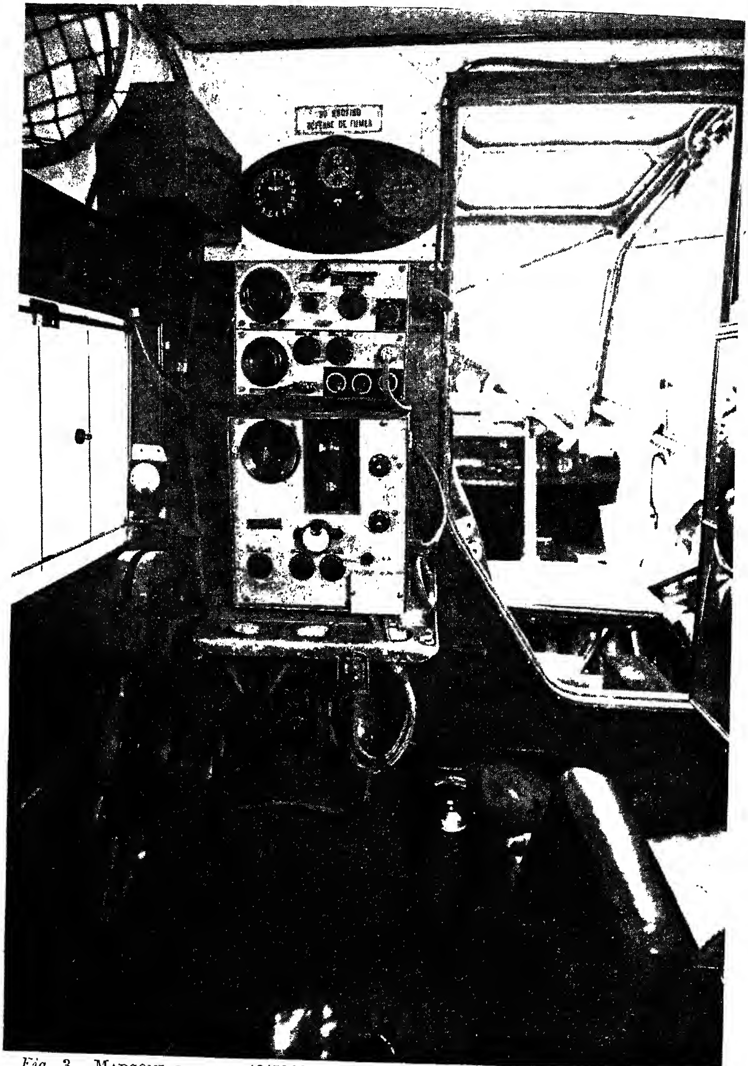


Fig. 3.—MARCONI TYPE AD49/5962 EQUIPMENT INSTALLED IN WESTLAND WESSEX AEROPLANE.

The Question of Available Space

Not the least of the troubles likely to be encountered, is lack of space to accommodate the radio equipment in a suitable manner or position. The apparatus must be protected from rain, and in seaplanes, also from spray. When accommodation in the cabin is possible, the trouble does not arise, but often the apparatus must be fitted in a space in the pilot's cockpit where rain can drive in through an open window.

Fire Risks

Fire risks from all causes must carefully be considered and apparatus with any type of sparking contact must not be fitted in a position where there is a possibility of an accumulation of fuel vapour.

The Designer's Work

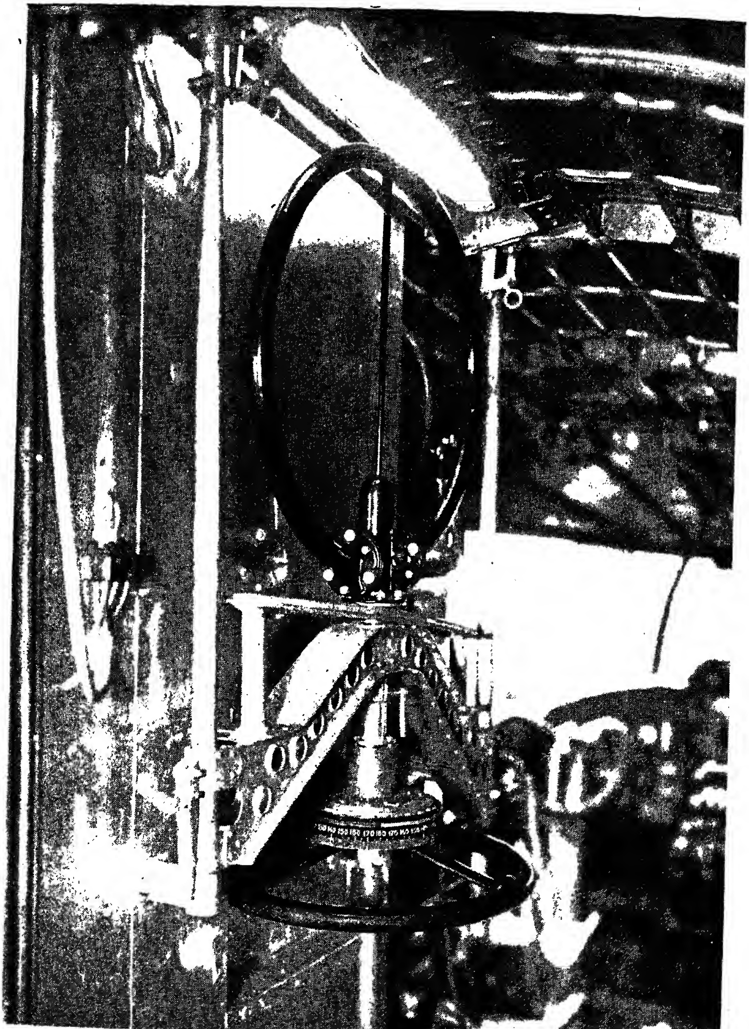
We will now consider some of the problems of development and design of the radio equipment.

The designer is concerned with (*a*) the aerial and earth system, (*b*) transmitting and receiving instrument box units, (*c*) power supply, (*d*) accessories.

When the circuits and general make-up of the equipment have been decided, the designer can get to work on the various units of the equipment. If he is acquainted with the type of aircraft in which the equipment is to be installed, his work is greatly facilitated.

Layout of Components

Each unit must be reduced to the least possible size and weight consistent with safety, performance and strength. Internal wiring is necessarily somewhat cramped and the greatest care must be exercised in the layout of components and wiring from the viewpoints of safety, accessibility and efficiency. The fire risk must, of course, be reduced to the absolute minimum. If the layout of components and wiring is not carefully considered, very troublesome interaction effects between circuits and capacity losses are likely to occur. Components should be firmly secured. Nuts should be secured either by a spring washer, locknut or shellac on the thread. Valves must fit firmly in their holders and suitable means should be provided to retain them in position if there is any doubt. Suitable locking devices should be provided for calibrated control dials, etc. Often it is necessary to arrange for the transmitter and receiver to be operated by remote control for such operations as change from send to receive, change from telegraph to telephone, wave changing and receiver tuning. Remote control may be accomplished by mechanical or electrical means. Bowden and similar cables in single and " push pull " types are often used and also a very light flexible shaft operated through worm reduction gearing.



[*Marconi's Wireless Telegraph Co. Ltd.*

Fig. 4.—RETRACTABLE ROTATABLE DIRECTION-FINDING FRAME AERIAL INSTALLED IN "C" CLASS EMPIRE FLYING BOAT (IN RETRACTED POSITION).

Shock Absorbing Suspension

It is very necessary that a shock absorbing suspension should be provided for the main instrument boxes otherwise vibration will cause interference with reception and transmission, and components will work loose. The suspension must also be good enough to take care of shocks at take-off and landing, otherwise the instrument boxes may crash against a bulkhead and be damaged or break adrift.

Fixings must be of such a nature that instruments are readily removable for servicing purposes.

Power Plugs and Sockets

Power plugs and sockets on interconnecting leads and instrument boxes can be a serious source of trouble. It is essential that they should make and maintain good connection and some form of lock to retain the plug in the socket should be provided. A cable running from a power supply should always carry the socket so that if it is disconnected and dropped on to metal there are no projecting live parts to cause a short circuit.

Interconnecting cables between units should be protected either by a tough rubber sheath or by flexible metallic conduit.

Sources of Electrical Power

Electrical power for the radio equipment may be obtained from the following sources :—

(*a*) A wind driven generator, preferably driven by a constant speed self-regulating windmill.

(*b*) A rotary transformer or dynamotor operated from the main battery. In this case charging facilities are necessary.

(*c*) A motor generator set operated from the main battery ; remarks under (*b*) also apply.

(*d*) A combined high and low tension generator driven by one of the main engines. A generator driven in this way is often used for charging the battery.

(*e*) Any combination of (*a*), (*b*), (*c*), (*d*).

(*f*) A dry battery. This is used only in the case of a low power transmitter or for a receiver only.

(*g*) A small engine driving a generator. This generally is used only for emergency working. (For this purpose a hand-driven generator may also be used if the transmitter is of very low power.)

The Emergency Power Supply

In the case of flying over isolated territory the question of emergency power supply in case of a forced landing is very important. The nature

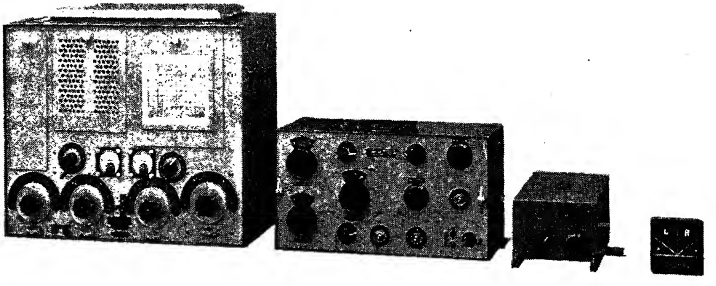


Fig. 5.—MARCONI TYPE AD67A/6872B/626C EQUIPMENT INSTALLED IN IMPERIAL AIRWAYS LONG-RANGE TRANSATLANTIC FLYING BOATS "CALEDONIA" AND "CAMBRIA."

of the emergency equipment must be decided by the likely conditions of use.

Aerial Systems

The aerial system used depends upon the type of aeroplane, equipment and service required. Aerial systems may be divided broadly into two classes (*a*) trailing, and (*b*) fixed. A trailing aerial is generally run out through a fairlead from a specially designed winch. The aerial length is usually of the order of 200 ft. with a string of lead alloy bead weights or a ball of about 1½ lbs. weight at the free end.

The Marconi Co. have used with great success for a number of years a 7/26 stranded phosphor bronze wire. Copper, stainless steel and Tungum wires are also in use. Tungum wire has an advantage for fixed aerial use on seaplanes as it does not corrode and is easier to handle than stainless steel.

Fixed Aerials

Fixed aerials, as the name implies, are fixed on to the structure and may take any of the following forms :—

(*a*) A single wire running from the tail fin to a lead-in point somewhere near the centre section of the wing.

(*b*) A wire as (*a*) but with two side limbs connected to it near the tail fin and running out to the wing tips, forming a broad arrow.

(*c*) Wires from wing tip to tail fin, with the lead-in taken from one wing tip.

(*d*) A tee aerial fitted under the fuselage and lower wing, the lead-in being taken from the junction of the tee.

(*e*) Large and small dipole aerials for short wave and ultra short wave working respectively, or fixed vertical rods.

(*f*) Loop aerials rotatable or fixed, for homing or direction finding purposes. A fixed loop aerial may take the form of a number of turns of insulated wire wound around the fuselage at a convenient point on a wooden or composite aeroplane. It now more usually takes the form of a winding inside a tubular metal loop of anything from 9 inches to 2 feet diameter. This tubular metal casing must not form a complete electrical circuit. It must be broken by a suitable insulating joint, otherwise a current cannot be induced in the winding by the radio wave.

Earthing

The earth terminal of the radio apparatus is usually connected to the bonded metal mass of the structure. A separate wire counterpoise has sometimes been used instead of the mass of the aeroplane for short wave telephony working. On electrically noisy aircraft this often reduced the noise level, but with modern bonding and screening this should not be necessary.

Trailing Aerials for Commercial 'Planes

A commercial aeroplane operating on wave lengths of the order of 900 metres may use a trailing aerial for normal working and change over to a fixed aerial when approaching the aerodrome. The fixed aerial may perhaps be used for short wave working, although the trailing aerial is sometimes used for this also.

A military single-seater fighter aeroplane will usually be fitted with a fixed aerial only, and in designing this aerial a clear exit should be left for the pilot in case he has to jump with his parachute.

Insulators for fixed aerials are preferably of porcelain or Pyrex glass. Aerial limbs are stretched taut by shock absorber elastic to which the insulator is attached.

Winches for the Trailing Aerial

The winch for the trailing aerial can be either hand or motor operated. Hand-operated winches are more common, but motor-operated winches are coming into use. The winch should be as flat as possible and the drum should be constructed from insulating material. Some form of automatic brake mechanism should be incorporated to prevent the wire running out too fast, otherwise the jerk when it stops, may cause the aerial and weight to break away. Air Ministry regulations call for the metal frame of the winch to be earthed.

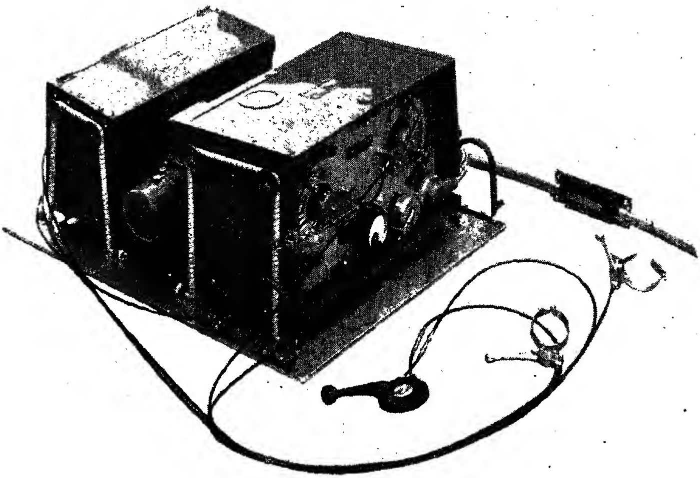


Fig. 6.—MARCONI TYPE AD63B/64B SHORT-WAVE TELEGRAPH/TELEPHONE EQUIPMENT FOR FIGHTER AEROPLANES.

The aerial fairlead generally consists of an insulated tube projecting through the fuselage which will give the aerial a runway clear of obstructions. A metal connection in some form must be provided at the top. A heavily insulated wire runs away from this connection to the radio instrument or to a change over switch for fixed or trailing aerial. The connection at the top of the fairlead may take the form of a spring clamp or it may be a metal bob held in a socket by the pull of the aerial. The main points are that it must be a firm connection and must not damage the wire.

The Earthing Switch

An earthing switch should be provided to earth the aerial to the mass of the structure in case bad electrical storm conditions are met. The aerial preferably should be earthed outside the aeroplane from the metal tip of the fairlead by a remotely controlled switch. Such a switch gives a measure of protection to the operator whilst the aerial is being wound in. Air Ministry regulations specify that it must be possible to earth and disconnect the aerial from the set. The same conditions apply to a fixed aerial, but in the case of a screened D.F. loop the danger from static charge is negligible.

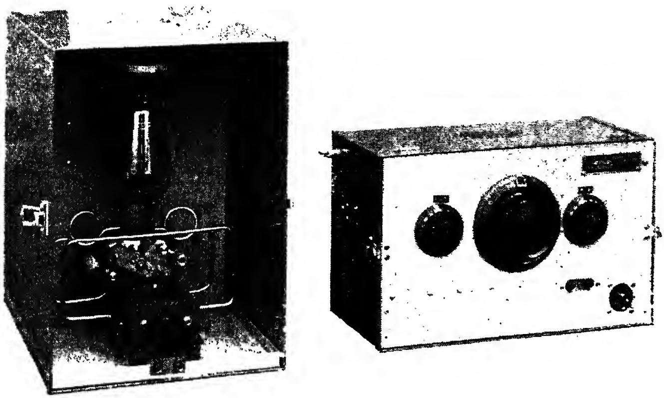


Fig. 7.—MARCONI ULTRA-SHORT-WAVE (1·8–2 M.) TELEGRAPH/TELEPHONE EQUIPMENT.

The Aerial Lead-in

The heavily insulated wire running from the aerial lead-in to the instrument boxes should be carried on insulating cleats and spaced away from the metal frame of the aeroplane, otherwise the capacity of the aerial circuit will be high and there may be bad losses. Great care should be taken where this wire passes through metal bulkheads or stiffeners; insulating bushes should be provided.

Instrument Casings

Transmitters and receivers are now generally fitted into light metal cases although light wooden boxes canvas covered have been used with great success. When designing the instruments, an endeavour should be made to reduce the back to front dimension as far as possible. This will generally make installation easier. Boxes may be made from sheet metal or light alloy castings. They must be fitted with some form of shock absorbing and vibration damping suspension, otherwise the purity of transmission and reception will be affected and troubles will develop in the instruments.

Receiver Dials

Dials of receivers under the direct control of an operator should be illuminated for night use. All controls should be plainly marked, and

it is preferable that instruments should be directly calibrated rather than to make it necessary to refer to a chart.

Housing a Wind-driven Generator

Wind-driven generators for power supply must be watertight under conditions of driving rain, otherwise serious trouble will be encountered. Brushes and commutators must be readily accessible for cleaning. It is often the modern practice to fit such generators in housings in the wing of the aeroplane. The housing must be watertight and generator easily removable for inspection. In some cases the wireless generator is also used to charge an accumulator and maintain the lighting supply. In this case a small charging switchboard fitted with battery cut-out, regulating resistance, ammeter and switch must be fitted.

Accumulators for Power Supply

Where nickel-iron batteries are used instead of the lead type of accumulator the problem of a steady voltage across valve filaments is more acute. It is often necessary to employ barretters in series with the valves to regulate the current.

Sources of High Tension Supply for Receiver

A separate small rotary transformer or dynamotor is often used for the high tension supply to the receiver and it is sometimes necessary to regulate this by a barretter also.

Fighter Aeroplane Requirements

Special attention must be given to the design of radio equipment for military aeroplanes, especially for the single-seater fighter class. Space in an aeroplane is very limited, and the main portion of the equipment generally is accommodated by fitting it into a skeleton crate which slides into a compartment behind the pilot. Fixed aerials are a necessity for this service, as the aeroplane may have to perform all kinds of aerobatics. Care must be taken that the aerial is so fitted that the pilot is not impeded in case he has to leave the aeroplane hurriedly by parachute.

Owing to the high speed of the modern fighter aeroplane the wind-driven generator is not in favour for power supply. Some low power equipments have been made for operation on dry batteries. Perhaps the best power supply for the fighter type of equipment is a rotary transformer or dynamotor run from the main battery (usually 12 volt), which is kept charged by a dynamo driven from the engine. Telephony is favoured for this service, although telegraphy is also used in some countries.

Microphone Equipment

The fighter aeroplane is noisy, and it is important that a suitable type of microphone should be chosen. The microphone is, as a rule,

fitted into a mask. This mask is used for the supply of oxygen to the pilot when flying at high altitudes, and it also serves to keep out much of the noise from the microphone. A well-fitting helmet with pockets over the ears to carry the telephones is necessary.

Microphone and telephone leads are often combined in a single cord, and should be terminated with a plug and socket connection which will easily part in case of necessity of a hurried parachute jump. Operation of the apparatus by remote control is very necessary for this service, and controls must be conveniently placed and suitable for operation by a gloved hand.

An intermediate waveband of say anything from 65–130 metres is suitable for fighter aeroplane service, although shorter waves have been used. It is likely that future requirements may be in the ultra short waveband.

Direction Finding and Homing Receiver Equipment

Direction finding and homing receiver equipment is used extensively on large commercial and military aeroplanes. "Homing," that is, flying a course to a definite transmitting station, necessitates only a fixed loop mounted athwartships. Sometimes a visual indicator is used for this service, which by the deflection of the indicator needle to the right or left shows deviation from the course. A full direction finding service, *i.e.*, the ability to take a bearing on a transmitting station in any direction demands a rotatable loop and a calibrated dial. Sometimes the ordinary communication receiver with the necessary change over switching to the loop aerial is used for the D.F. service but often special equipment is carried.

MANUFACTURE OF THERMOMETERS

By Wing-Commander G. W. Williamson, O.B.E., M.C., M.Inst.C.E., M.I.Mech.E., M.I.E.E.

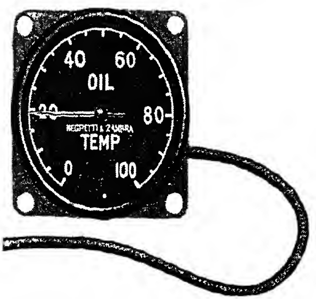
Disadvantages of Glass Thermometers

THE word thermometer for most people refers to a slender glass tube with a bulb at one end filled with mercury or with alcohol coloured red or black. The tube is graduated in degrees Fahrenheit or Centigrade and the indication of the temperature is read directly from the movement of the thin column of liquid.

For aeroplane use glass thermometers would have many disadvantages. They would be easily broken by shock or vibration, and the indication is difficult to read as compared with that of a pointer on a dial. It is impossible to arrange for glass thermometers to be distantly read, so that, for example, the temperature of the liquid in the radiator should be indicated in the pilot's cockpit.

Distant Reading Thermometer

For these reasons, distant reading thermometers are essential for aeroplanes and have considerable advantages in industrial temperature measurements. The indicator is of the circular dial type, connected by a capillary tube to the bulb at the point where the temperature is to be measured. This system does not measure temperature by means of direct indication of the expansion or contraction of a liquid, as in the glass thermometers ; but instead that expansion or contraction is used in some types to influence the pressure in a sealed system, the indicating instrument being in effect a pressure gauge to measure these changes in the closed circuit.



[*Negretti & Zambra*

Fig. 1.—Radiator thermometer dial.

The indication is always on a circular dial, so that without reading the actual figures a pilot is able to note by a casual glance the attitude at which the indicating needle stands ; and, finally, the dial indicator can be as much as 100 ft. away from the bulb without affecting the accuracy.

Types of Distant Reading Thermometer

There are three types of distant reading thermometer; those in which the sealed system is filled by a gas such as nitrogen, systems only partly filled with some volatile liquid such as ether or completely filled with one of several suitable liquids.

In gas-filled thermometers it is the pressure of the gas itself in the indicator which gives a pressure reading proportional to the temperature of the bulb; but in the vapour pressure type, all the system excepting a portion of the bulb contains the liquid as it distils over, and it is an increase or decrease in the vapour pressure which is measured by the indicator.

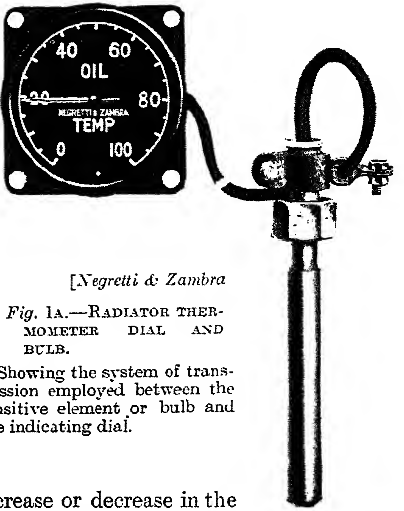


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Fig. 1A.—RADIATOR THERMOMETER DIAL AND BULB.

Showing the system of transmission employed between the sensitive element or bulb and the indicating dial.

In such cases the indicator is only a pressure gauge, and as such may be expected to bear a close resemblance in its construction and operation to those described in the article beginning on page 782 of Volume I. There will be, however, a different construction depending upon the measurements to which these instruments are to be applied.

In an aeroplane, thermometers may be used to measure the temperature of the liquid in the radiator, the air outside, the air inside the intake pipes of the engine or at one or more points in the oil system. Some engines are provided with oil thermometers at the beginning and end of the circulation system, so that the rise in temperature during the passage of the oil through the engine can be measured by the difference between the two readings.

Radiator Thermometers

The simplest of these is the radiator thermometer. It is usually of the vapour-filled pattern, the bulb being about half filled with ether or some similar liquid.

The appearance of the instrument dial is shown in Fig. 1, and as the following illustration Fig. 1A will serve to show the general appearance of the bulb, transmission and dial, the succeeding figures will be confined to interior details or points in construction.

The bulb is generally placed in the uptake pipe of the liquid cooling jacket or in the top of the radiator where the liquid is hottest.

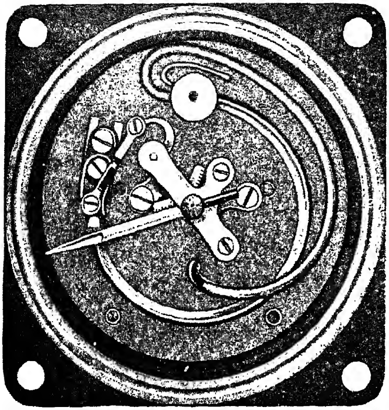

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Fig. 2.—INTERIOR OF RADIATOR THERMOMETER.

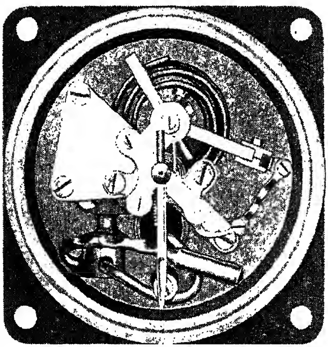

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Fig. 3.—INTERIOR OF AIR TEMPERATURE THERMOMETER.

The indicator mounted on the dashboard gives warning of overheating or of the loss of engine cooling water, a mark on the dial indicating the boiling point of the liquid at an altitude of 20,000 ft.

The scale of the ether vapour pressure transmitting thermometer does not extend below 50° C., as the scale becomes very close below this temperature. In cases where an indication is required of temperatures below this point, the mercury-in-steel type radiator thermometer is recommended.

The indicator, which, as stated previously, is essentially a pressure gauge, has a phosphor-bronze Bourdon tube, connected to the sensitive bulb by small-bore capillary tubing. This system is almost filled with ethyl alcohol, and the vapour pressure of the liquid in the bulb is indicated on the dial, which is marked in corresponding temperatures.

The indicator case is of black moulded material with a $2\frac{1}{2}$ in. square flange and the capillary has a braided and waterproofed protective covering.

The simplicity of this type of gauge with its single curve of a Bourdon tube is at once apparent, as in Fig. 2.

Air Temperature Thermometer

The radiator thermometer cannot be called upon to measure temperatures outside the range between 0° C. and 100° C., and the ethyl alcohol vapour pressure type will therefore be satisfactory, but alterations in vapour pressure at low temperatures are so small as to result in inaccuracy. Some other type of thermometer is therefore used for temperatures below 40° C.

The air intake thermometer, the inside of which is illustrated in Fig. 3, is slightly more complex than the radiator thermometer previously described. The Bourdon tube has three or four coils, instead of a single bend. In both instruments a multiplying mechanism connects the end of the Bourdon tube to the pointer.

This instrument is intended to work with a system filled with nitrogen gas, as the extremely low temperatures which may be met with in attempts at altitude records may cause mercury to freeze, while vapour pressure bulbs are out of the question.

Air temperature thermometers are usually mounted on a strut or elsewhere clear of the warmth of the engine. The bulb is provided with a shield which ensures that the direct rays of the sun do not reach it.

Air temperature thermometers are generally made with mercury in a steel system, if the air temperature is not expected to be below minus 36° C., this being the lowest temperature marked on the scale of a mercury type gauge. This system is suited not only for the measurement of the temperature of the outside air in aeroplanes which are not likely to be used at great altitude, but is also satisfactory for the measurement of air temperature in the engine intake.

Oil Temperature Thermometer

By means of an indicator on

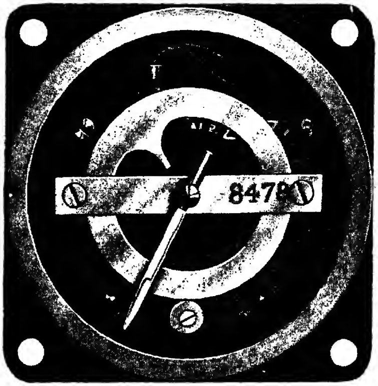

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Fig. 4.—INTERIOR OF OIL TEMPERATURE THERMOMETER.

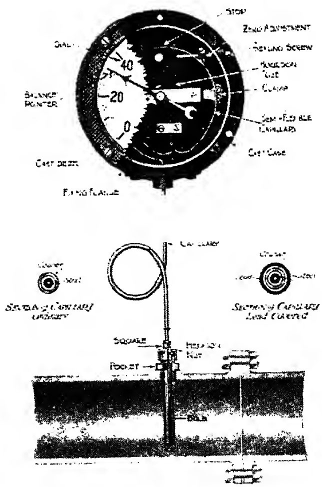

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Fig. 5.—PRINCIPLE OF MERCURY-IN-STEEL THERMOMETER.

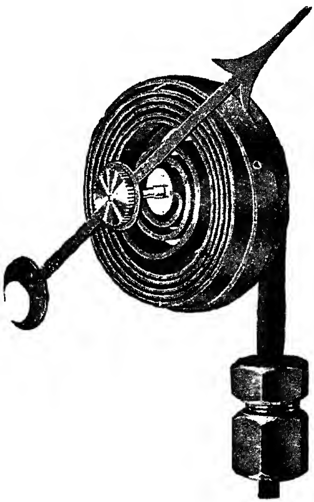

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Fig. 6.—BOURDON TUBE FOR DIAL THERMOMETER.

the instrument board, the transmitting oil temperature thermometer shows the temperature of the oil in the engine lubricating system. With every type of engine, the oil temperature is an important indication as to whether the engine is functioning normally or otherwise. In the case of an air-cooled engine it is often the only means of ascertaining the temperature conditions existing.

The gauge illustrated in Fig. 4 operates on the liquid expansion principle. Mercury under pressure is contained in a sealed steel system, comprising a Bourdon tube of patented design which is connected to the sensitive bulb by the required length of very fine-bore tubing, all joints being welded. The change of volume of the mercury, following upon change of temperature, is exerted directly on the Bourdon. The Bourdon tube operates the pointer directly and the movement is mounted in a $2\frac{1}{2}$-in. square flanged case of black moulded material. The easily bent capillary is protected by a waterproofed braided cotton covering.

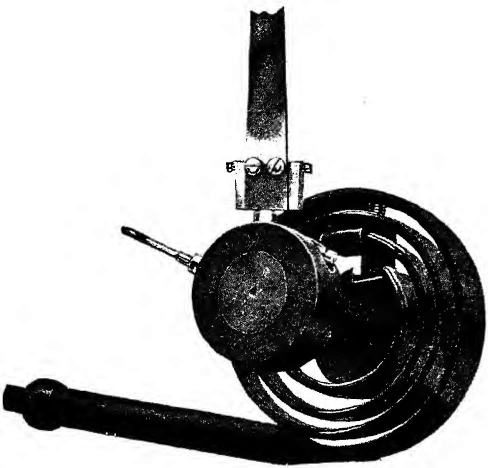

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Fig. 7.—BOURDON TUBE FOR RECORDING THERMOMETER.

Construction of Transmitting Thermometers

The method of operation of one of these transmitting thermometers will in all probability be clear from the preceding description and from the figures showing the inside of the indicators. A more detailed illus-

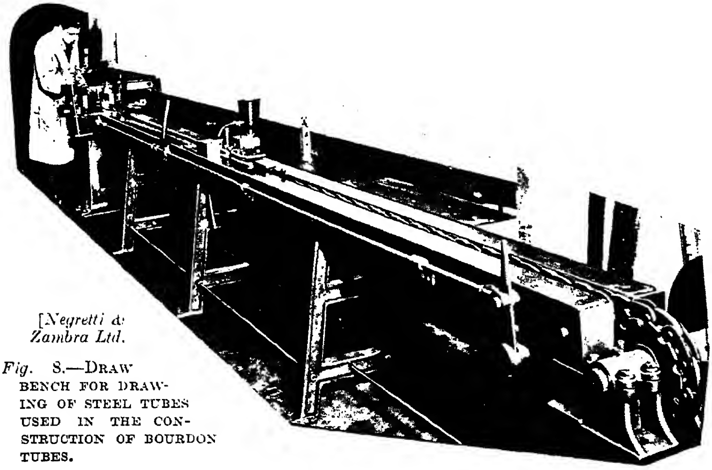

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Fig. 8.—DRAW BENCH FOR DRAWING OF STEEL TUBES USED IN THE CONSTRUCTION OF BOURDON TUBES.

tration appears at Fig. 5, which shows portions of the dial, the Bourdon tube and pointer and the method of connection between the end of the capillary and the beginning of the tube.

It will be noticed that the Bourdon tube in this figure consists of at least six coils; the number might quite easily be as many as twelve coils by the insertion of a similar unit in series with it, coiled so that both open in the same direction. The instrument illustrated is not necessarily an aeroplane type, but the principle is the same.

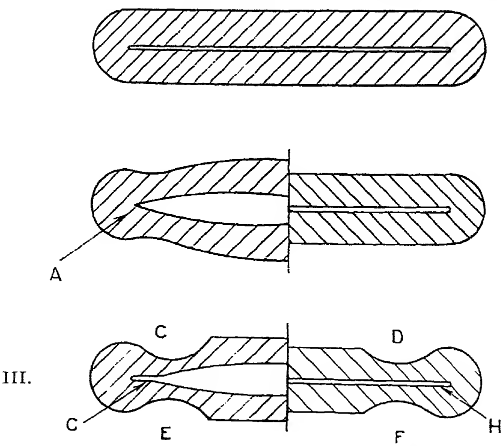

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Fig. 9.—DESIGN OF INDUSTRIAL BOURDON TUBE.

Production of Bourdon Tube

The effect of this number of coils is to permit the

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Fig. 10.—ROLLING BOURDON TUBE.

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Fig. 11.—SWAGING BOURDON TUBE.

tube to operate the pointer directly; this entirely eliminates the necessity for using magnifying levers with the usual accompanying links, quadrant and pinion mechanism.

The type of Bourdon tube used in dial instruments is shown in Fig. 6, whilst Fig. 7 shows a tube used for a recording thermometer.

The Bourdon tubes are of steel which have been formed to an almost

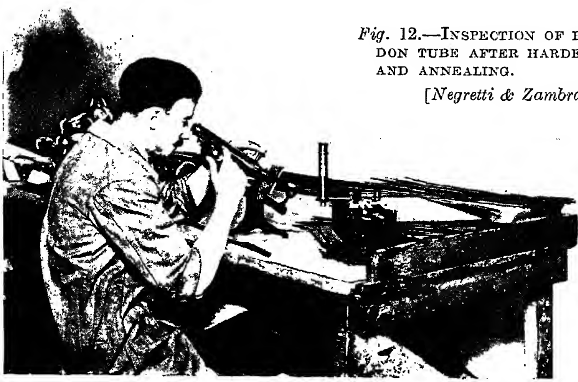

Fig. 12.—INSPECTION OF BOURDON TUBE AFTER HARDENING AND ANNEALING.

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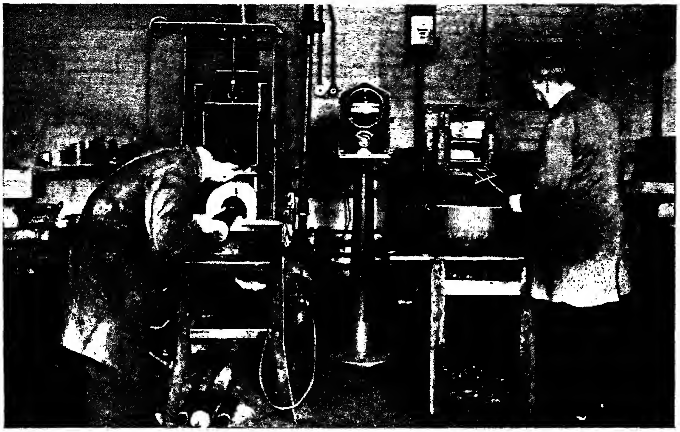

Fig. 13.—HARDENING, TEMPERING AND ANNEALING BOURDON TUBES.

flat section—that in Fig. 6 has two continuous coils, each of several turns, both ends being situated near the centre of the coil. One end is fixed and leads to the capillary; the other end, which is closed, is attached to a small bi-metallic coil which compensates for change of temperature of the Bourdon and which forms a continuation of the Bourdon coil. This is attached directly to the pointer spindle. The outermost turn of the Bourdon leading from the back coil to the front coil is clearly seen.

On heating the bulb of the thermometer, the great expansion of the mercury contained in it causes it to flow through the capillary to the Bourdon tube, which to accommodate an increased volume of mercury undergoes an increase in its sectional area, the tube assuming, to a small extent, a less flattened form, an alteration which in turn causes it to unwind.

Owing to the special formation of the tube, the pointer would thus be caused to rotate about its axis, even if there were no bearings for its spindle. Actually bearings are provided so that the pointer will be steady under vibration, but, as there is little or no load on them, there is no appreciable friction and no error due to backlash.

The control afforded by this form of tube is much greater than that usually found in dial thermometers. It is unnecessary, for instance, to tap the indicator to obtain an accurate reading. A further advantage is that, owing to no part of the movement being out of balance, there is no position error or error due to an acceleration of the instrument in any direction.

The Bourdon tube is drawn down to the required dimensions on a draw bench such as that illustrated in Fig. 8. When the tube has been

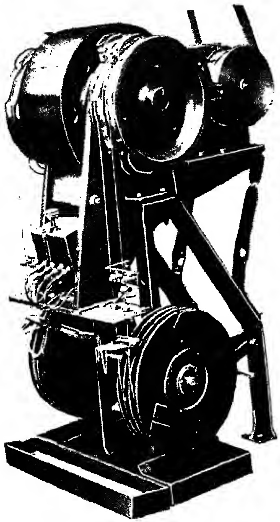

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Fig. 14.—DRAW BENCH FOR CAPILLARY TUBE.

brought down to the required size it is flattened upon itself to reduce the internal volume to an absolute minimum.

A tube formed in this manner but with refinements of design is illustrated in Fig. 9 at I; a Bourdon tube formed in this manner will fail by fracture due to the stresses set up in the edges, when the tube is subjected to a number of dilations.

The usual Bourdon tube is based upon this design. In II the section is shown dilated, but for illustration purposes exaggerated. The strains are concentrated at "A" and failure occurs at this point.

Diagram III shows a section of the Negretti and Zambra patented Bourdon tube.

The thickness of the walls of the flattened tube is reduced at "C," "D," "E" and "F," thus relieving the stresses at "G" and "H." The right-hand half of the section is shown not dilated, and the left-hand dilated, but exaggerated.

Rolling and swaging of the Bourdon tubes are carried out as illustrated in Figs. 10 and 11; in making the single length of tube, the swaging is repeated six times.

Inspection, as in Fig. 12, is carried out between these operations and again after the hardening, tempering and annealing illustrated in Fig. 13.

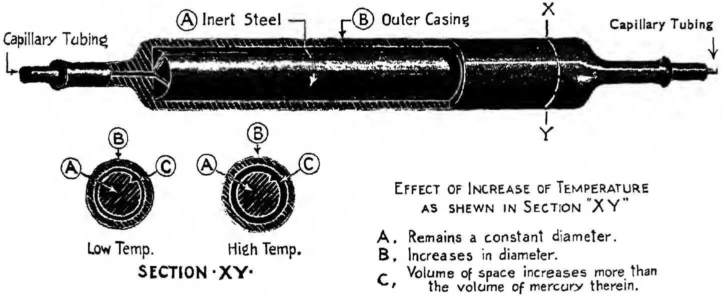


Fig. 15.—COMPENSATING LINK IN CAPILLARY.

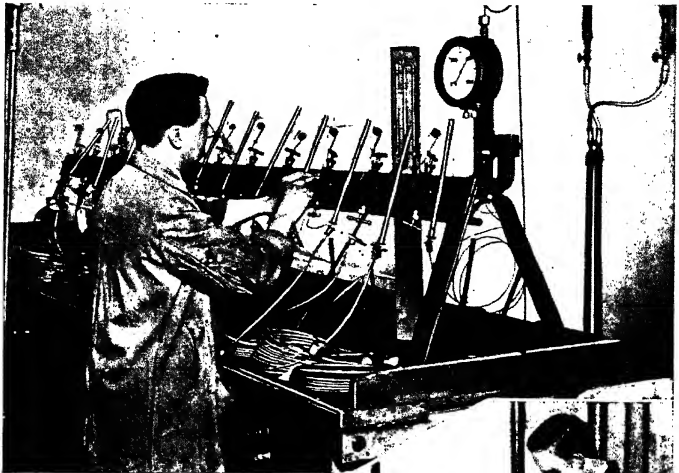


Fig. 16.—Mercury filling apparatus.

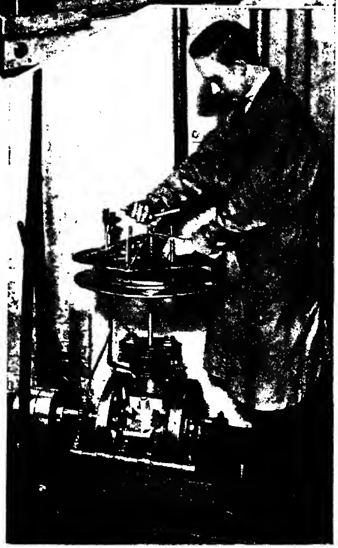


Fig. 17.—Capillary vibration machine.

Manufacture of Capillary Tubing

Like the Bourdon tube, the capillary is also steel and is produced upon a capillary drawing machine designed like the draw bench; it is illustrated in Fig. 14.

After drawing and sandblasting, the machine shown in Fig. 17 releases every particle of sand, which is then blown out by compressed air.

It is of the greatest importance that the volume of mercury in the capillary tube should be small as compared with the volume in the bulb, if not, temperature changes anywhere on the capillary away from the bulb would result in errors in the reading of the indicator. The capillary tube is therefore drawn down until the diameter of the bore is no more than ·005 in. How small this diameter is will be realised when the capacity of one mile of such capillary tubing is only one cubic inch of mercury.

In long capillaries, in even a small bore, the variation in volume of the

contained mercury may not be negligible if the surrounding temperature varies considerably, and compensating links are then introduced as required along the length of the tube. One is shown in Fig. 15. The outer casing of steel contains a rod of Invar, a material whose change of dimension with alteration of temperature is infinitesimal. The mercury in the capillary passes through the annular space between the Invar and outer casing; supposing that an increase in temperature results in expansion of the mercury, it will also expand the steel outer casing of the compensating link, but the size of the Invar rod remains constant, with the result that the annular space is increased in volume to an amount sufficient to take up an expansion of the mercury which would otherwise result in a false reading on the gauge.

Filling the System

The bulb, illustrated in Fig. 1 and diagrammatically in Fig. 5, is of nickel plated steel having a flare outlet from which the capillary projects. Connecting points between capillary and bulb, and the tube and Bourdon are all welded.

Before the system can be sealed off, it has to be filled. This operation is shown at Fig. 16, the system being first exhausted and then filled with mercury under a pressure of 2,000 lbs. per square inch. Twelve instruments are filled at one time.

Prior to calibration, the complete system undergoes ageing treatment, and selected instruments may be put under test in a fatigue testing machine.

INTERCHANGEABILITY

By A. F. Bennell, A.R.C.Sc., Wh. Ex.

THE effectiveness of an aeroplane, civil or military, is directly dependent upon its being in an airworthy condition. It therefore follows that the time required for maintenance other than for the work connected with routine inspection must be kept down to a minimum. In order to comply with the above conditions, all parts required for replacement, due to wear or damage, must be strictly interchangeable, *i.e.*, they must be capable of being fitted to the aeroplane without the necessity of making any alterations to the shape or attachment holes.

Having specified our requirements, we will now consider what measures must be taken by the manufacturer to produce an aeroplane providing to an agreed degree this all-important feature "interchangeability." In the first place, we will assume that the aeroplane is a twin-engined monoplane with monocoque fuselage and metal-covered wings, and is to be manufactured in such quantities that the time and cost required for producing the jigs and tools will justify the details being fully tooled up. The items to be considered fall broadly into two groups, viz., components and details, and we will consider each in turn.

Components

These items, which are self-contained units, are affected by the interchangeability requirements in so far that they must be capable of being attached to their "mating" components without any fitting of the joints. To this end the ease with which this feature is accomplished is a direct reflection on the skill of the designer and the limits which it is found necessary to specify on the drawings. In addition to the fixed joints, we have a further group of hinge connections for moving surfaces. The diagram, Fig. 1, illustrates the main points on a typical aeroplane, which require special provision to ensure that components are interchangeable. The details are as follows :—

AA. Front fuselage to rear fuselage and centre plane.
BB. Rear fuselage to centre plane.
CC. Stern frame to rear frame.
DD. Tail plane to stern frame.
EE. Elevator to tail plane.
FF. Rudder to fin and stern frame.
GG. Fin to stern frame.
HH. Outer plane to centre plane.
II. Centre plane flaps to centre plane.
JJ. Outer plane flaps to outer plane.

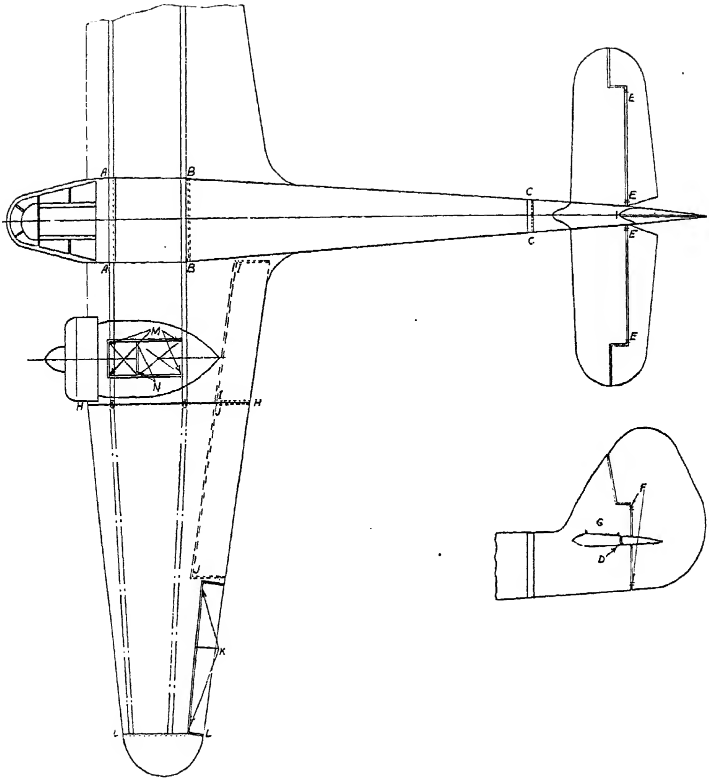


Fig. 1.—MAIN JUNCTION POINTS ON TYPICAL AEROPLANE.

AA. Front fuselage to rear fuselage and centre plane.
BB. Rear fuselage to centre plane.
CC. Stern frame to rear frame.
DD. Tail plane to stern frame.
EE. Elevator to tail plane.
FF. Rudder to fin and stern frame.
GG. Fin to stern frame.
HH. Outer plane to centre plane.
II. Centre plane flaps to centre plane.
JJ. Outer plane flaps to outer plane.
KK. Aileron to outer plane.
LL. Outer plane tip to outer plane.
MM. Engine nacelle to centre plane and engine mounting.
NN. Undercarriage to engine nacelle.

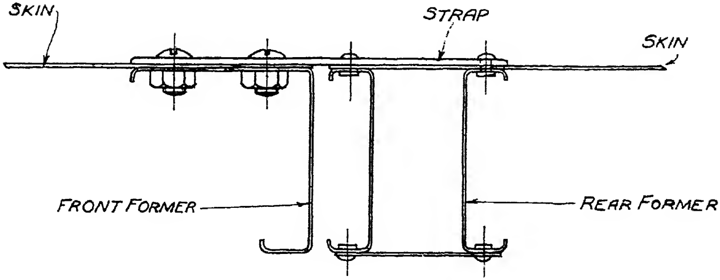
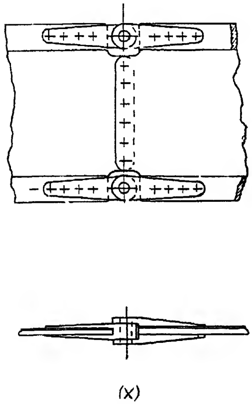


Fig. 2.—TYPICAL MONOCOQUE FUSELAGE JOINT.



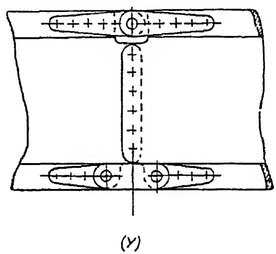
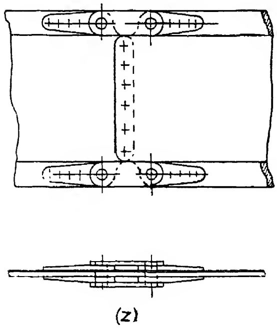


Fig. 3.—MAIN SPAR JOINTS.



KK. Aileron to outer plane.
LL. Outer plane tip to outer plane.
MM. Engine nacelle to centre plane and engine mounting.
NN. Undercarriage to engine nacelle.

The joints listed above fall into three groups :—

(*a*) Skin-covering junctions where the attachment to be made is dependent on the form of the section being constant, and that the holes for picking up the screws are always in the same relative positions. The junction of rear fuselage and stern frame is an example of this type.

(*b*) Points joined by machined fittings in the form of forked ends and bolts. The junction of centre and outer plane are typical of this form.

(*c*) Hinged attachment points made up of two or more hinges. The ailerons and flaps are two examples of this attachment.

We will now analyse the three groups and determine how interchangeability is to be effected.

(a) Skin-covering Junctions

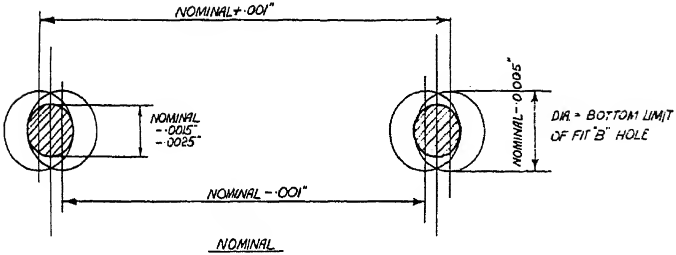
The general form will be as shown in Fig. 2, and it will be noted that there are two main points to cover : (1) the shape of the formers ; (2) the correct drilling of the strap plate and rear former.

1. *Formers.* Templates will first be made to give the outside contour of the formers, and these will be used as " standards " in making suitable assembly boards. Referring to Fig. 2, the front former will be made so that its upper limit for external dimension is not greater than nominal and the rear former will have its lower limit nominal. In addition to the above, a further allowance should be made for the tolerances on sheet thickness. The foregoing procedure will ensure that the rear portion will always assemble over the front.

2. *Drilling jigs* will be required for both the front and rear portions ; the most positive method is to make up one of the jigs accurately and use this jig as a reference to produce the other jig. Generally the holes are normal to the contour and do not lend themselves to being spaced with the accuracy obtained by jig boring, and consequently jig reference plates will be required, and these will be retained in the Standards Department against replacement of either of the jigs. Suitable datum holes, positioned from the templates, will be provided on the formers to act as locations for jigging. With the above procedure carefully followed, complete interchangeability for this class of junction will be attained.

(b) Points Joined by Machined Fittings

A typical example of this class of joint is that between the centre and outer plane spar attachments of a deep section monoplane wing. The joints may be of the direct-coupled " solid " type, both at the top



Exaggerated view showing bolts fitted through two pair of holes whose centres are on the top and bottom limits respectively.

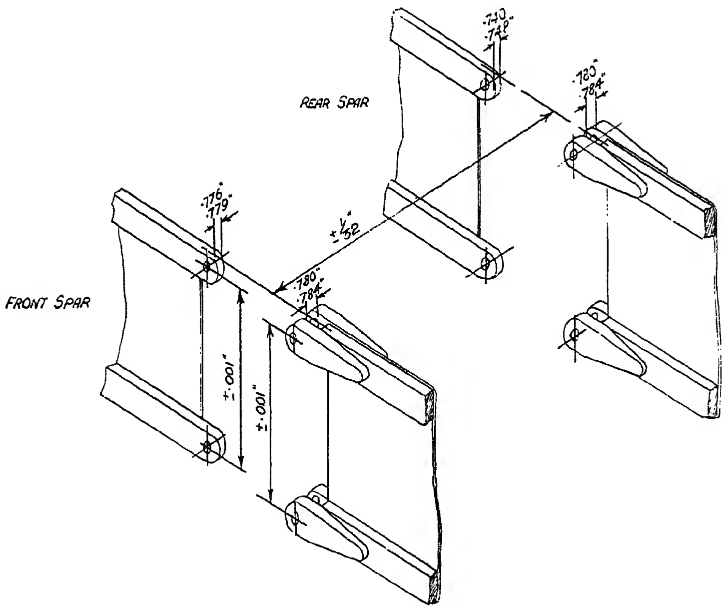


Fig. 4.—LIMITS ON MAIN SPAR JOINTS.

and bottom fittings, or having one or two links as shown in Fig. 3, X, Y, Z. Taking type Y as an example, it will be noticed that the introduction of the link at the lower portion of the joint allows for sufficient variation in the centres of the main bolt holes in the top and bottom fittings on the centre and outer planes to enable interchangeability to be readily achieved. The jaws of the fittings will mate within the limits specified for the front spar and have clearance for the rear spar. Should it be necessary to take drag loads on the rear spars in addition to the front, shims must be fitted to suit the gap on assembly of the outer to the centre plane. One method of producing the centre plane component would be on the following lines: the spars would have the main holes in their end fittings drilled and reamed to jig as a final operation, the finished size of holes leaving sufficient for a further reaming operation.

The centre plane is now assembled on jigs which locate the spars correctly at the end fittings.

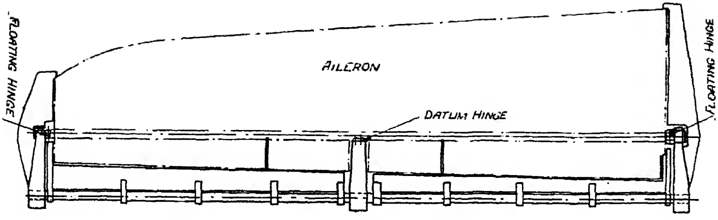
Reaming Fixture

A reaming fixture is next prepared to take the finished component. To set up this fixture, which supports the component at its standard fittings, a reference gauge is necessary, which is made to the closest limits possible and is constructed to obtain high torsional rigidity, so that in effect the gauge is a solid rectangular block with representative fittings at its eight corners. Having verified that the end fixtures satisfy the gauge requirements, the centre plane component is offered up and the main bolt holes reamed one at a time.

As a result of this operation we have the four holes in each end lying in parallel planes and at correct pitch within close limits and the top and bottom holes in any one spar and also spaced at centres within the specified limits. It should be noted that this method ensures that diagonal measurements are correct, but cannot influence any " out of pitch " between front and rear spars.

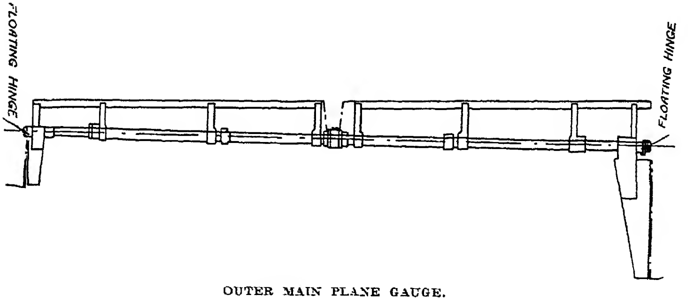
The allowance in the rear jaw clearances must accommodate the variations of spar centres obtained as a result of differences of spar details and individual assembly jigs. In addition to the link, which can have its holes jig-drilled to close limits, it may be necessary to introduce a web junction plate to deal with the main vertical shear loads.

Type X joint offers certain attractions from the design point of view, carrying as it does the shear loads on both top and bottom fittings. If we refer to Fig. 4, it will be seen that using pins, which on their high limit give ·001 in. clearance on the low limit of the hole, the reamed holes in the component must fall within centres limited to $\pm$ ·001 in. In addition, it should also be noted that the solid joint makes the group extremely sensitive to diagonal variations. When one considers that the limit on the reference gauge, plus the variation due to setting up reaming fixtures and reaming holes, must not total more than ·001 in., it is obvious



When gauging without skin use ·093 in. feelers.

AILERON GAUGE.



OUTER MAIN PLANE GAUGE.

Fig. 5.—HINGED ATTACHMENT POINTS.

Hinge interchangeability gauges will be made up to the limits shown for both the aileron and outer main plane hinge points and both components must accept these gauges before they can be passed as satisfactory.

that this type of joint does not lend itself to the provision of an interchangeable unit.

(c) Hinged Attachment Points

If we refer to the list of components which must be interchangeable, it will be noted that the group of items which are hinged comprise the control surfaces, *i.e.*, ailerons, elevators, rudder and flaps. In order that interchangeability can be effected it is not only necessary to ensure that the hinged points are correctly positioned relative to datum, but also that the required clearances are maintained between fixed and moving surfaces. We are therefore committed to two groups of gauges—(1) hinges ; (2) clearances.

Hinges

Taking an aileron as an example, we assume that it is built in an assembly jig which will give a product within the limits specified on the component drawing (see Fig. 5). The hinge positions on the outer main plane will also be jig-located during assembly. Hinge interchangeability gauges will be made up to the limits shown in Fig. 5 for both the aileron and outer main plane hinge points and both components must accept these gauges before they can be passed as satisfactory.

Clearances

It is important that a careful check be made on the clearances for both the fixed and moving surfaces. Taking the aileron as an example, it will be noted from Fig. 5 that limit of size must be checked along the leading edge, on the two end ribs, the gap provided for the centre hinge post and the upper surface forward of the hinge. The gauge will therefore be made up on the lines indicated and its dimensions will be governed by the upper limits on the component drawing.

In the case of fabric-covered components the gauge will be offered up after the covering and doping is completed ; it may also be considered desirable to have an auxiliary gauge for use in the Assembly Department which has the allowance made for the thickness of fabric, sewing, etc.

The gauge for the outer main plane will be as indicated in Fig. 5, and it will be noticed that a check is made on the fairing member both for clearance of the aileron nose and also the upper forward surface of the aileron when the latter has to be rotated through its maximum angle. In actual practice the gauges for hinges and clearances are incorporated into one unit.

SUB-ASSEMBLIES AND DETAILS

Sub-assemblies

In order to facilitate production, group assembly of secondary parts of the aeroplane is carried out where possible. These groups are assembled

in jigs, and there are certain points which are related directly to other parts of the structure, generally in the form of bolting down positions. To ensure that these groups can be fitted without modification, the assembly jigs must produce accurately these basic points within the required limits, or, alternatively, reaming jigs must be provided which can be used after the group assembly is removed from the building jig.

In addition to the group assembly, there are also the mating points on the aeroplane to be considered. These points will either be incorporated in the main assembly fixture or a separate drilling and reaming jig will be used for correctly making of the holes in their true positions relative to datum. There are many classes of groups which fall within this category, the following being typical :—

1. Seat structures and control units.
2. Tank support bearers and panels.
3. Engine cowling and support structure.
4. Hinged or removable doors.
5. Control countershafts and brackets.

We will now consider items (1) and (3) in detail.

1. Seat Structures

Assuming that the seat structure itself is made of tubular construction, either jointed by welding or fishplates, and is held down in the manner shown in Fig. 6, viz., by bolts through the fore and aft beams on the monocoque floor and at the rear end in channel brackets. The beam members would be jig-drilled, the holes being spaced accurately from the rear end which butts on to the bulkhead.

The main assembly fixture would provide means for locating the beams from the jig-drilled holes in their correct position relative to the bulkhead, and, in addition, spacing blocks would hold the vertical channel brackets true relative to the beams. When the unit is removed from the building jig the holes in the vertical brackets are jig-drilled, the jig locating on the holes in the beams. After the seat assembly is removed from its building jig it is placed into a box-drilling jig and all the location holes drilled. The unit will now assemble into the fuselage without the necessity for further work on the location points.

3. Engine Cowling and Support Structure

For the work of producing interchangeable cowling and support structure the following equipment is essential :—

(*a*) Assembly and drilling jigs for locating the support structure and drilling when necessary.

(*b*) Master reference jigs for (*a*).

(*c*) Jigs for shaping, trimming to size and drilling panels.

(*d*) Master templates for panels.

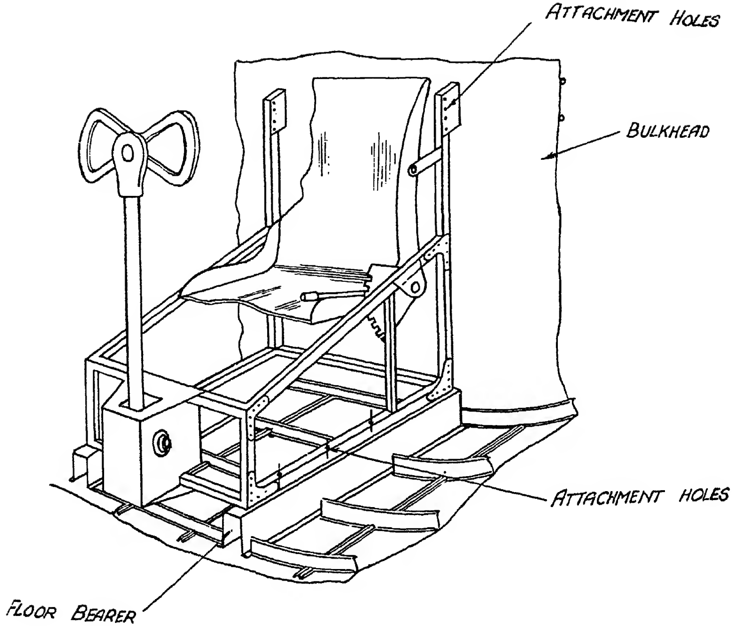


Fig. 6.—SEAT STRUCTURE ASSEMBLY.

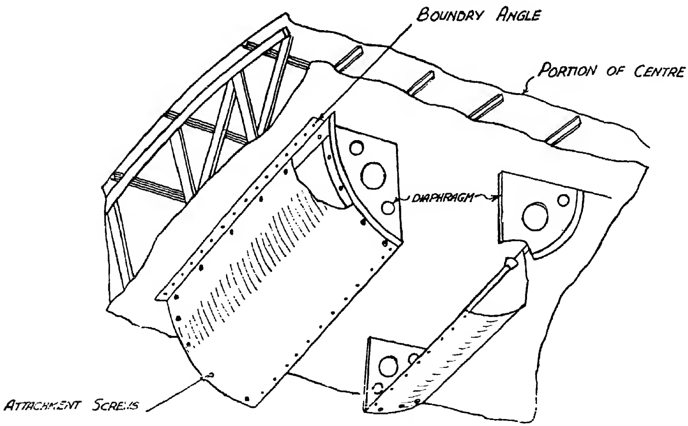


Fig. 7.—ENGINE COWLING PANEL ASSEMBLY.

The procedure is to set up the support structure, using jigs (*a*), which are located from basic points on the aeroplane, such as main joint connections between centre and outer plane for a twin-engined aeroplane. The panels will be completed in detail on jigs (*c*), and will not require any further fitting or drilling when offered up for assembly.

Details

The two main features in details necessary to provide interchangeability are that the shape and hole positions shall be constant.

For sheet metal work the shape is controlled by master templates, if cut out and formed by hand and if blanked on press tools the first off is carefully checked against the master templates before mass production is started up. In the case of machined details, when these are made from forgings the first off the dies is put through a rigid check for shape. When parts are machined from bar, using form tools and gauges, each petail requires individual check to determine it accurately to drawing dimensions.

With regard to hole positions, box or plate drilling jigs can readily be made with the drill bush housings jig-bored within very close limits.

Although certain individual uses may arise, as, for example, a group of " B " fit holes to match in two plates, which require one jig to be used as a reference for producing its opposite number, generally speaking, no great difficulty is associated in the accurate production of this part of the work to give interchangeability of details.

THE MANUFACTURE AND MAINTENANCE OF PARACHUTES

WITH NOTES ON OPERATION

THE parachute has been called the "Lifebuoy of the Air," and as a device for saving life it certainly merits this description. Already the Caterpillar Club, which comprises all those who have saved their lives in emergency with Irvin Parachutes, numbers over 1,600 and new members are being added almost daily. It is interesting to speculate how many valuable lives would have been saved in the Great War had parachutes been universally in use as they are to-day.

General Principle

The general principle of the modern parachute is that of a self-contained unit operated at will by exerting a moderate pull on a rip-cord ring. It is obviously desirable that the occupant of an aeroplane leaving it in emergency should be well clear of it before his parachute comes into action and the rip cord should therefore not be "pulled" until he has dropped sufficiently far to be clear. The parachute opens almost instantaneously, the small auxiliary parachute opening first and helping the main canopy to unfold. The opened parachute then brings the wearer gently and comfortably to earth.

Manufacture of Canopy

The way in which parachutes are made has several interesting features, and the following is a description of the methods used in the manufacture of Irvin Parachutes.

The parachute canopy is made up of a total of ninety-six pieces of silk, called panels. The silk, which is of British manufacture, conforms to a special specification and has to withstand on test a minimum "bursting" strain of 140 lbs. to the square inch. The panels are cut on the bias from rolls of silk laid out in lengths on a cutting table.

Four panels of different sizes are sewn together with two rows of stitching to form a gore. The gore is in the shape of a triangle with the apex cut off. This is in order to form the "vent" at the top of the parachute. Twenty-four gores of four panels each make up the canopy, and the gores are stitched each to the other by four rows of stitching.

The necessary folding is done by a special "folder" and the length of seam controlled by a pulling device incorporated in the sewing machine.

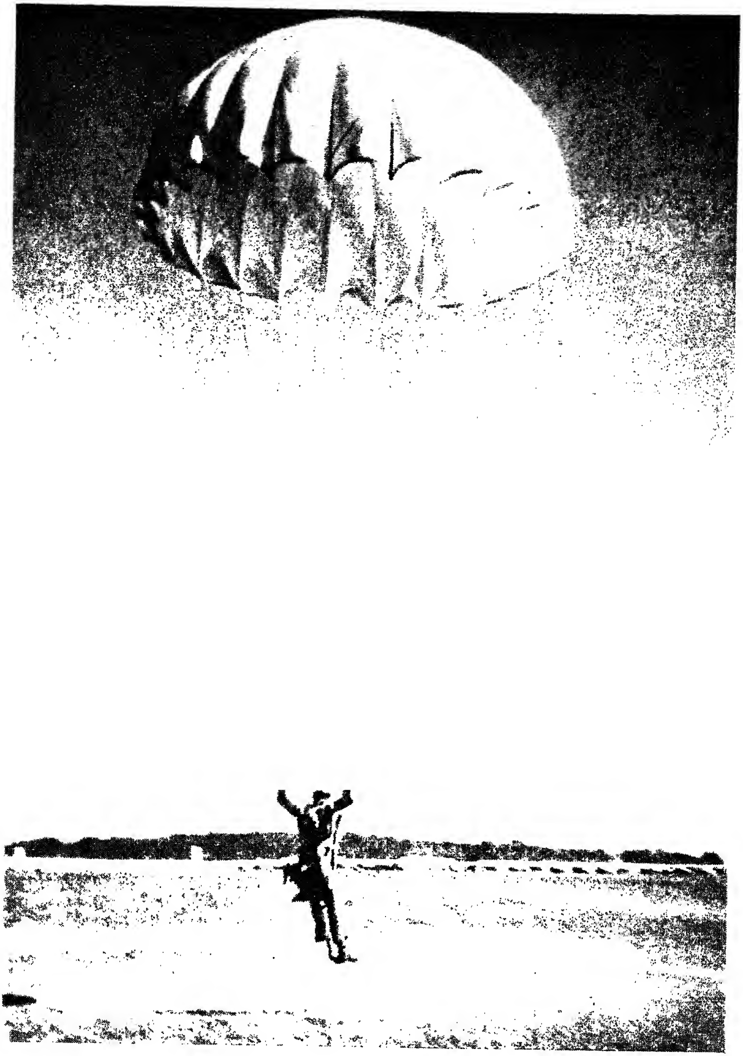


Fig. 1.—A PARACHUTE DESCENT.

The landing should be made as far as possible on the toes and with the knees flexed.

The next step is the reinforcing of the skirt and vent of the canopy and this is done with silk tape. At the vent, where the greatest strain will come, several thicknesses of silk tape are used. The diameter of the canopy at the skirt is 24 ft. and at the vent 2 ft.

The purpose of the vent is to "spill" air during the descent and to minimise oscillation of the parachute. There are approximately a quarter of a million stitches in a complete canopy, silk thread being used. The canopy undergoes a very searching inspection for missed or broken stitches.

The Rigging Lines

The rigging lines which connect the parachute with the harness are made of braided silk cord with a minimum breaking strain of 400 lbs. There are twelve of these, each one approximately 20 yds. long but doubled on itself, so that there are twelve loops at the vent and twenty-four ends. The line is threaded through between the two centre lines of stitching at the junction of the gores so that one-half of it is at the opposite side of the canopy to the other.

Before the lines are "strung" they are marked under tension to ensure that they are fixed in the right position at the vent and skirt after stringing. After the stringing is completed, and the lines have been stitched in position with a special machine, the canopy is ready for tying-on to the harness.

The Harness

The harness is made of heavy linen webbing with a breaking strain of at least 4,500 lbs. There are metal adaptors of stainless steel to enable the harness to be readily adjusted and a quick release fitting consisting of a junction box and four lugs allows the wearer instantly to release himself from the harness after landing.

On the seat type parachute harness there are four lift webs of heavy webbing. On the end of each is sewn very strongly, in the loop of the webbing, a stainless steel "D" ring.

When the canopy is "tied on" to the harness, six of the rigging lines are tied on to each of these "D" rings. The markings on the rigging lines ensure that they are tied on to the right length and are even. After the tying on, the loose ends are fastened to the rigging lines by stitching to ensure that there is no slip.

The parachute is then ready for packing.

Packing

The container or pack is made of canvas with a framework of steel wire to stiffen it. It is constructed more or less on the envelope principle with four flaps, one with two cones, the opposite one with two eyelets, and the smaller end ones each with a pierced metal lug.

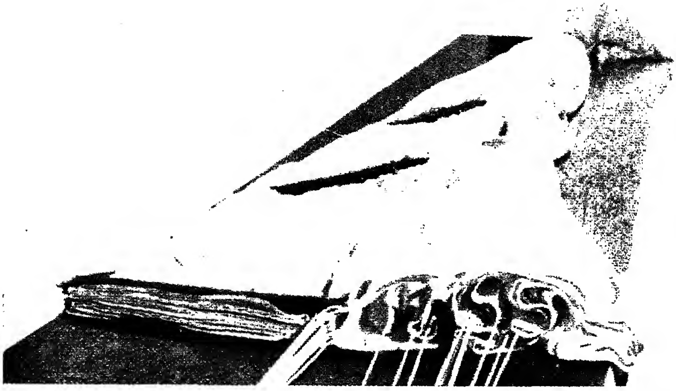


Fig. 2.—ONE-HALF OF THE SILK PANELS NEATLY FOLDED AND HELD IN PLACE BY SHOT BAGS.

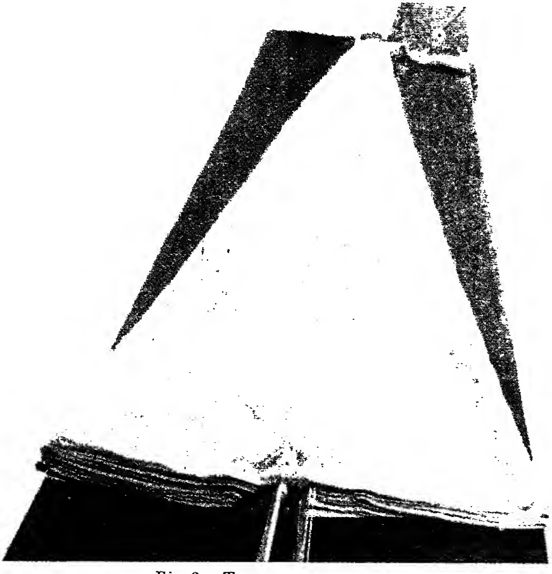


Fig. 3.—THE SILK BODY FOLDED.
Note shroud lines are together and in the centre with half of panels on each side.

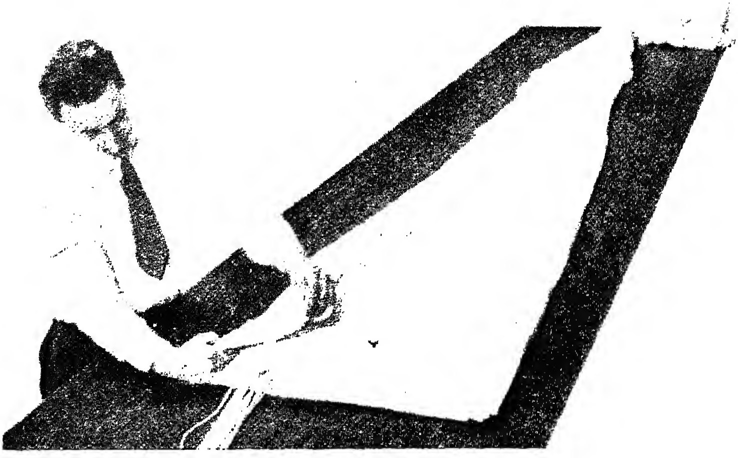


Fig. 4.—FOLDING ONE GROUP OF PANELS BACK ON TO THE SILK BODY.

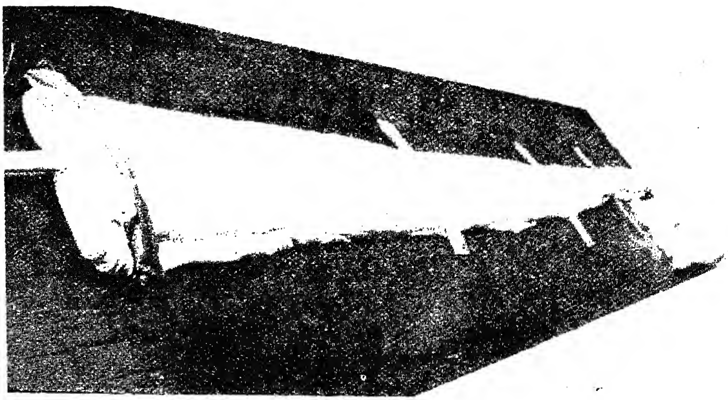


Fig. 5.—THE FOLDED PARACHUTE.

For packing, the parachute is laid out at full length on a table, the rigging line loops at the vent being hooked on to a fitting at one end of the table to "anchor" the parachute. The canopy is then "pleated" into folds like those of an umbrella on each side of the centre panel, which bears the makers' stamp and the serial number of the parachute.

Before this is done, the rigging lines have to be checked carefully to see that they are straight and not tangled up. The pleats are folded in from the sides towards the middle of the centre panel to correspond with the width of the pack.

The rigging lines are now inserted, in loops, into the pockets made for them in the pack cover, alternately from one side to the other. These pockets take practically the whole of the length of the rigging lines, the canopy being gradually drawn nearer the pack cover during the process until the skirt reaches the edge of the pack cover. The skirt end of the canopy is lifted into the pack cover and placed in position to fill completely the available area of the pack cover. The canopy is then folded on itself so that it is all within the limits of the cover.

The two large flaps of the cover are then drawn together, the eyelets of the one being placed over the cones of the other and the two flaps are held together by temporary pins through the holes in the cones.

The next step is to remove one pin and pass a piece of cord through the hole in the cone. This cord is taken through the lug on the end flap and the lug is then pulled over the corresponding cone and the rip-cord pin inserted.

The Rip Cord

The rip cord is a length of cable with two pins of steel wire wrapped and soldered on to it at one end, and a metal ring at the other. In the seat-type parachute, the rip-cord cable is protected from damage by a flexible metal sheath. This is sewn at one end to the pack cover close to one of the lugs, and at the other end to a wide belt of webbing on the harness to which the rip-cord pocket is stitched.

The rip cord is passed through a hole in the rear of the rip-cord pocket and then through the metal sheath or housing so that the rip-cord pins are at one end of the housing and the rip-cord ring at the other. The rip-cord ring fits into the pocket and is retained in position by an elastic reinforcement to the edge of the pocket. It is located on the left side of the chest within easy reach of the right hand.

The Auxiliary Parachute

It is now necessary to insert the auxiliary parachute. This is made of the same silk as the canopy and has rigging lines of silk cord with a minimum breaking strain of 100 lbs. It has a spring steel frame to enable it to open quickly and remain open. It is tied on to the cords at the vent with a piece of heavy silk cord and then compressed and put into the remaining open end of the pack above the top fold of the canopy. The

apex is inserted first and the rigging lines are looped together and put in last.

Finally, the remaining end flap is drawn into position in the same way as the first, the lug pulled over its corresponding cone, and the second rip-cord pin inserted into the hole in the cone.

It is now only necessary for the pack to be shaped by manipulation and the use of a little wooden stick.

When the shaping of the packed parachute is completed, the pack elastics are put on. There are six of these in all with a hook at each end. These hooks are fastened to eyes on the pack cover so that they are at their optimum stretch and this ensures quick opening of the parachute pack cover when the rip cord is pulled.

Operation

The sequence of events when the rip cord is pulled is as follows :—

The pins are withdrawn from the cones and with the help of the stretched elastics the four flaps of the parachute pack cover fly open. Immediately the pressure is released, the auxiliary parachute springs out and opens, fills with air and in acting as an anchor assists the main canopy to get clear of the cover. As the tension on the rigging lines begins, they are pulled out of their retaining pockets in the pack cover until finally the lift webs to which they are attached are also drawn clear of the pack cover and upwards. The pack cover remains in the same position, it being fastened to the harness by press studs.

The parachute canopy opening out and filling with air begins to take up the load and the lift webs tighten upon the shoulders of the wearer through the fitting which connects the two lift webs on each shoulder. If at the time, as is often the case, the parachutist is on his back in relation to the earth below, the canopy brings him into a normal position again, seated comfortably in his harness. At first he is swinging a little from side to side, but this soon ceases and the steady gradual descent to earth begins.

As he gets nearer the ground the parachutist is able to control the direction of his drift by pulling down the edge of the parachute in the required direction. This is done by grasping the corresponding lift webs or rigging lines. By this means it is possible to avoid landing on obstructions such as trees or houses.

The rate of descent is approximately 16 ft. per second and the shock of landing is equivalent only to a jump from a 9-ft. wall. The landing is made as far as possible on the toes and with the knees flexed. Immediately he lands, the parachutist frees himself from the harness with the quick release device and gathers the canopy into a bundle to prevent it blowing away.

Maintenance

It is essential that parachutes should be kept dry and free from damp,

and that they should be aired and repacked at regular intervals not in any case exceeding three months.

For airing, a parachute should be suspended from the roof in such a way that the canopy hangs at its full length with the skirt well clear of the floor. If the building is high enough, the pack cover should be taken up with the vent of the parachute, and the rigging lines allowed to hang in a loop. If this is not possible, the rigging lines and pack cover should be accommodated in a trough or tray to keep them clear of the dirt and dust of the floor. The parachute should be hung in this way for at least twenty-four hours, care being taken to avoid exposure to sunlight, which is detrimental to silk fabric.

Packing and general maintenance should be done only by a competent ground engineer with an "X" licence endorsed for the type of parachute which is to be packed or maintained.

Points to be looked for in the routine examination which should precede the repacking of a parachute are, in the case of the canopy, the general condition of the silk fabric and rigging lines and whether there are any tears and broken stitching or signs of staining. It sometimes happens that the silk has been exposed to acid corrosion, and this is especially detrimental.

The harness has also to be examined for damage or corrosion by acid. It is important that the selvedge edges should not be frayed.

The effective life of a parachute depends very largely on the efficiency of its maintenance. There are records of parachutes which have been in use for more than ten years.

THE LOCKHEED ELECTRA 10A

SOME POINTS IN ASSEMBLY AND CONSTRUCTION SHOWN PICTORIALLY

Fig. 1.—THE LOCKHEED ELECTRA 10A.
A three-quarter front view.

WE show in the following pages some of the most interesting features in the assembly and construction of the Lockheed Electra 10A. These photographs were taken by the courtesy of Messrs. British Airways Ltd.

As will be seen from Fig. 1 this aeroplane is a two-engined low wing monoplane, fitted with Hamilton constant speed airscrew. Deicer equipment is fitted on the wings and tailplane.

The wheels are retractable (see Fig. 6).

The interior of the pilot's cockpit is shown in Fig. 7, and Fig. 12 shows the general appearance of the inside from the rear of the cabin.

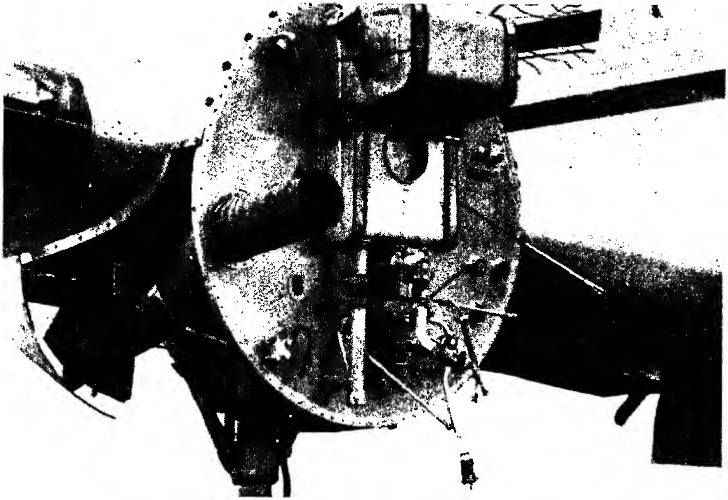


Fig. 2.—FIREPROOF BULKHEAD WITH ENGINE DISMOUNTED.
The complete installation is readily detachable to facilitate engine changes.

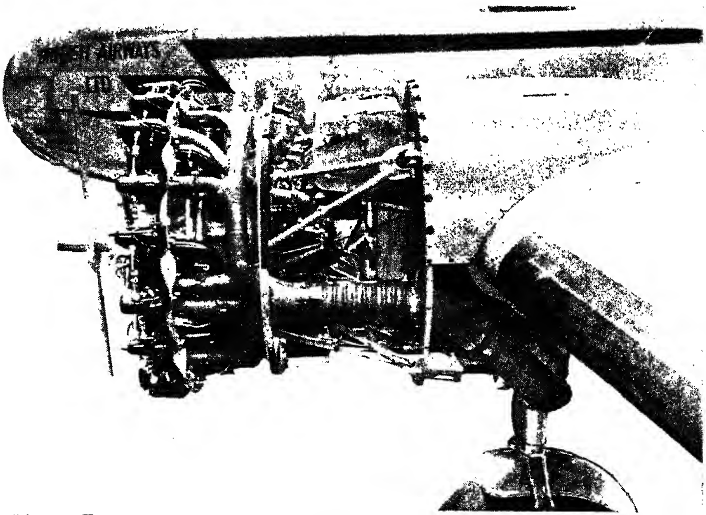
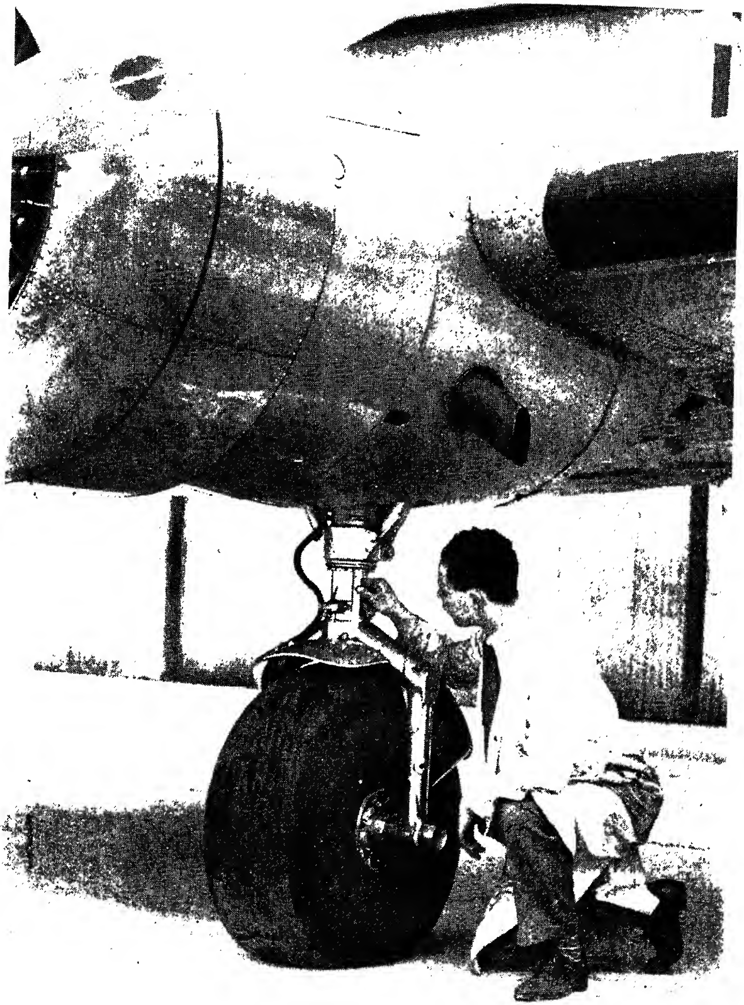


Fig. 3.—THE PRATT AND WHITNEY WASP JUNIOR S.B. INSTALLATION UNCOWLED.



4.—CHECKING THE COMPRESSION LEG.
is kept constant
compression leg.

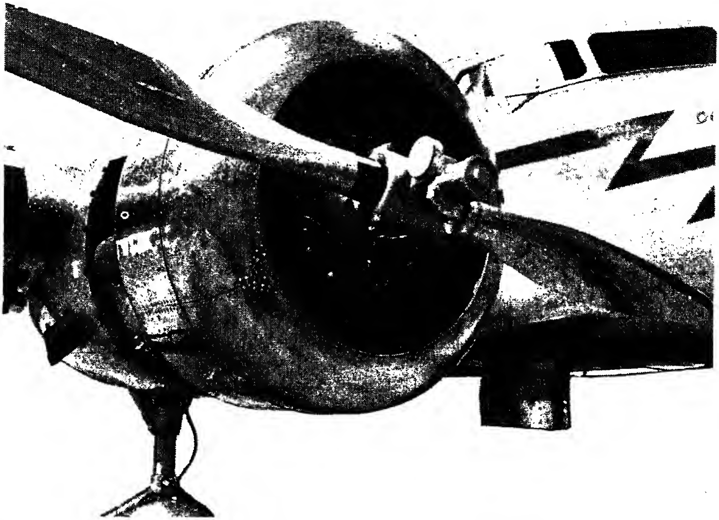


Fig. 5.—SHOWING ENGINE COWL AND HAMILTON CONSTANT SPEED AIRSCREW.

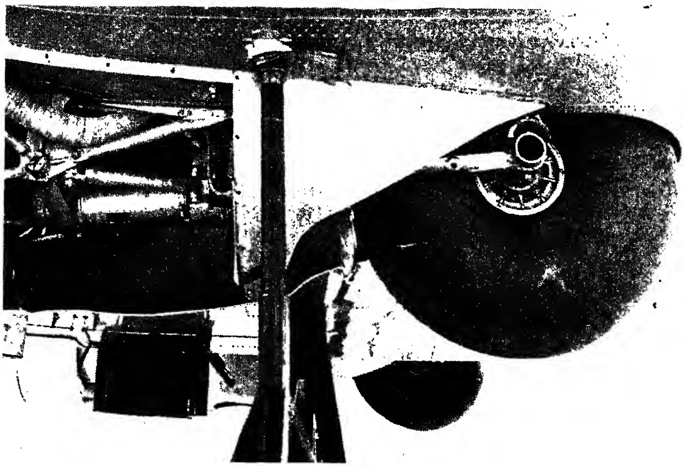


Fig. 6.—WHEELS RETRACTED INTO WELLS BEHIND THE ENGINE MOUNTING.
Note dropped position of accumulator cage which facilitates battery changing and servicing.

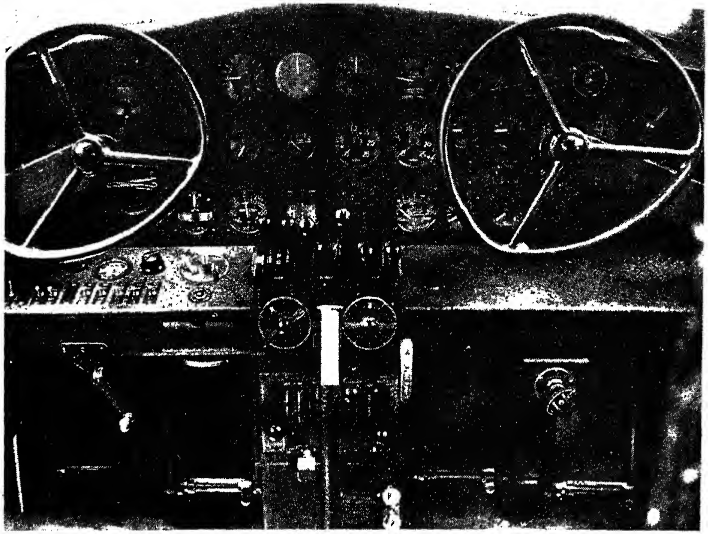


Fig. 7.—INTERIOR OF PILOT'S COCKPIT SHOWING INSTRUMENTS

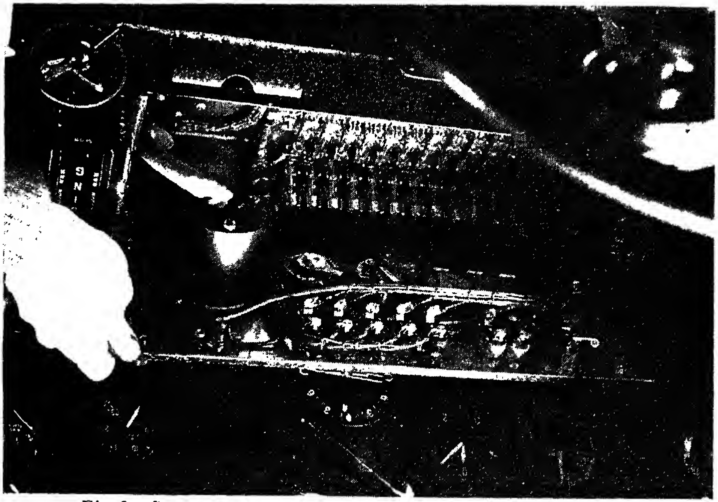


Fig. 8.—SHOWING THE UNDERSIDE OF SWITCH PANEL AND FUSE BOX.

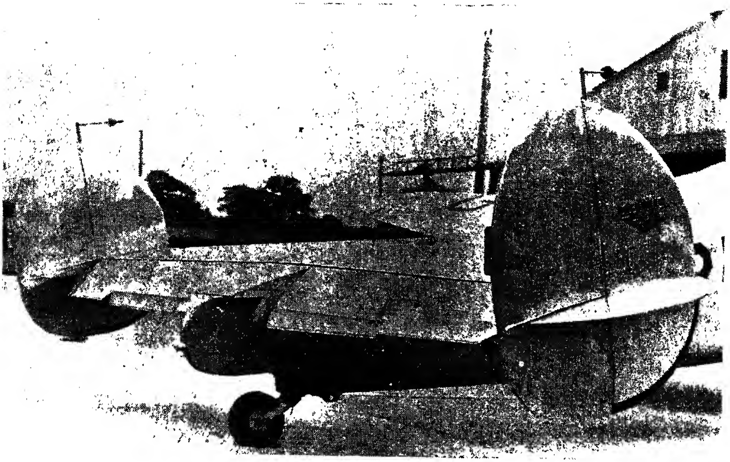


Fig. 9.—The tail unit.
Showing elevators down. Note the tail-adjusting gear trimming tabs.

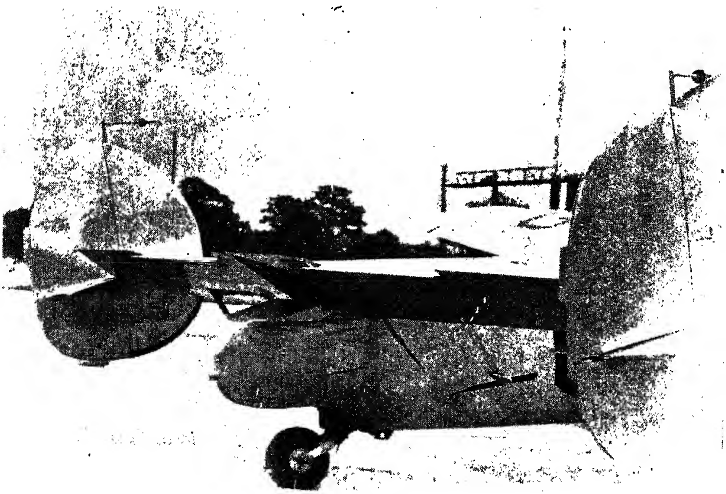
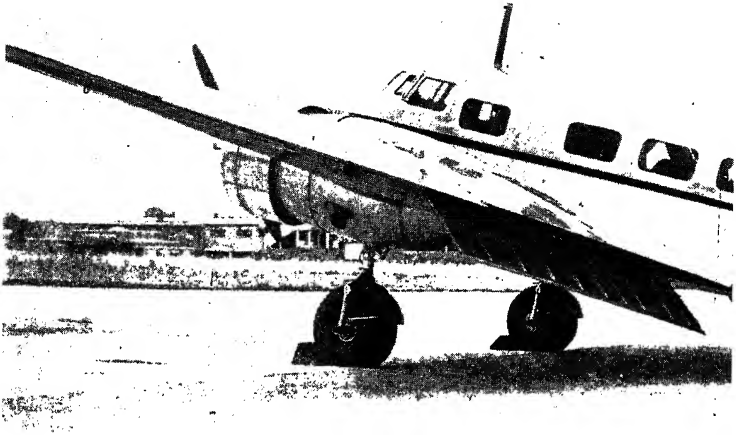


Fig. 10.—The tail unit.
Elevators up. Note centre portion between elevators which is lifted with the elevators.



11.—VIEW SHOWING WING FLAPS IN DOWN POSITION.

Fig. 12.—THE INTERIOR OF THE LOCKHEED ELECTRA 10A.
View from rear of cabin, through wireless cabin into the pilot's cockpit.

RUDDER AND ELEVATOR ADJUSTMENT

THE following series of photographs illustrate stages in the method of adjusting the rudder and elevators of the Percival Vega Gull aeroplane.

Fig. 1 shows the method of holding the rudder in line with the fin whilst the cables are being adjusted for alignment. The rudder in the cabin is set to neutral and the cable adjusted accordingly under the fuselage.

Fig. 2 illustrates the method of holding the rudder bar straight by means of a strip of wood.

Fig. 3 illustrates the first stage in adjusting the elevators. The extent of elevation is marked on the stick at the point of widest chord on elevator. The elevator is first placed in the appropriate position and the cables adjusted accordingly under the fuselage.

In Fig. 4 the elevator is at lowest point and the control is positioned accordingly for similar adjustment.

The neutral mark is also made with the control stick in neutral. The distance between neutral mark on stick and highest point of elevation should equal the distance between neutral and lowest point of elevation.

We are indebted to Messrs. Airwork Ltd., of Heston, for facilities for staging the photographs.

Fig. 1.—METHOD OF HOLDING RUDDER IN LINE WITH FIN WHILST CABLES ARE ADJUSTED.

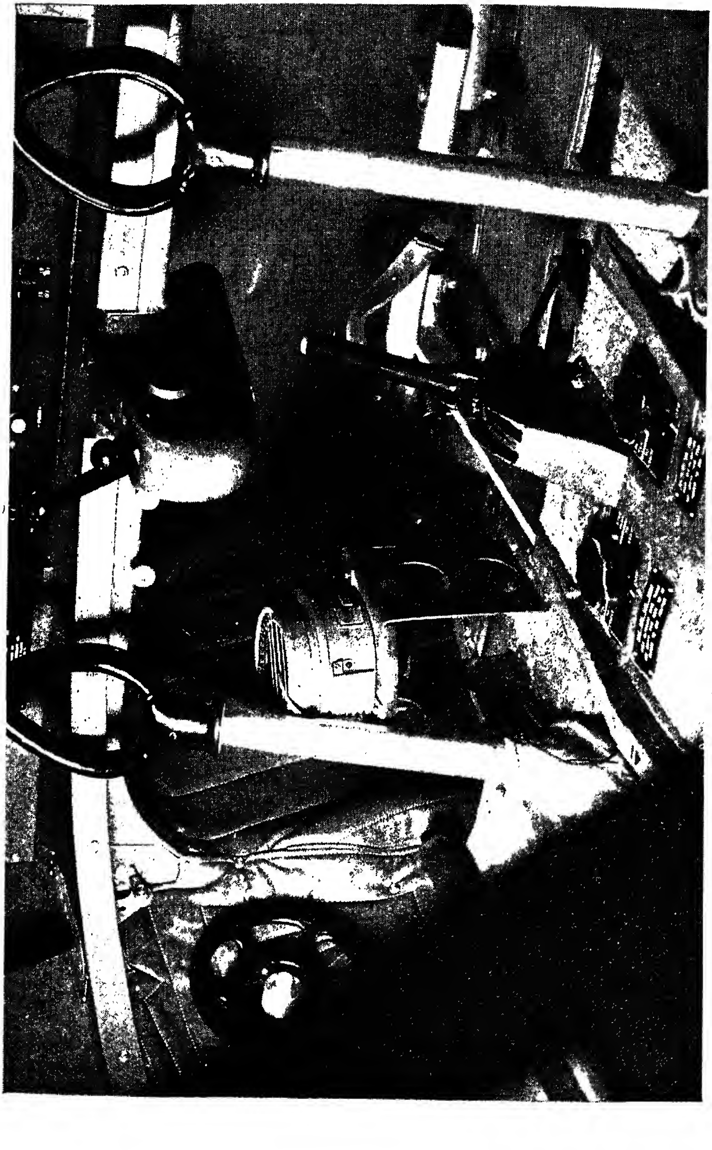


Fig. 2.—METHOD OF HOLDING RUDDER BAR STRAIGHT.
Note strip of wood to fasten rudder bar.

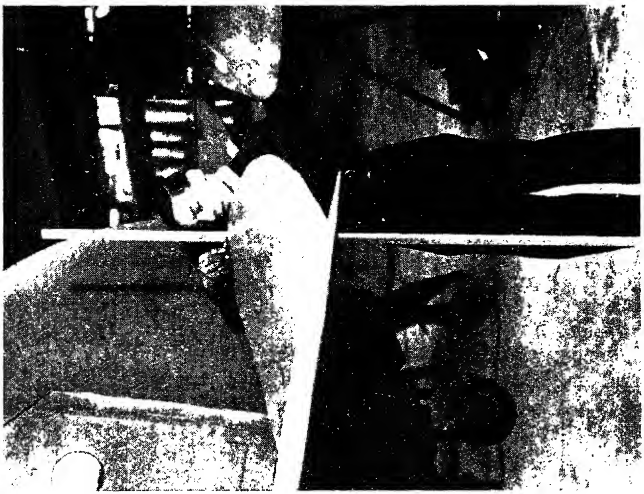


Fig. 3.—METHOD OF ADJUSTING ELEVATORS.

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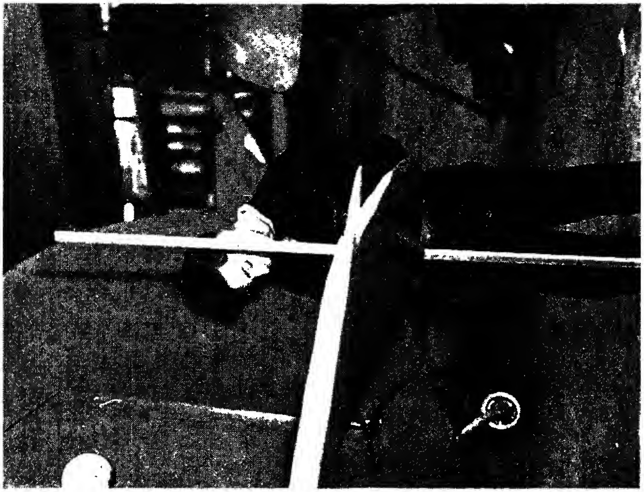


Fig. 4.—METHOD OF ADJUSTING ELEVATORS.

Elevator in lowest position.

NOTES ON "DOPING-STRIPS" FOR FABRIC COVERING

Fig. 1.—LINEN STRIPS BEING SERRATED TO PERMIT SEAMS TO LIE FLAT

THE following illustrations show stages in the fixing of "doping-strips" to the fabric covering of panels of aeroplane wings.

After the linen strips have been given a coat of red dope, strips of fabric which are called "doping-strips" are laid on the still tacky dope and rubbed down until the dope begins to ooze through.

They are then given a final coat of red dope to produce a strong watertight seal.

It will be seen in Fig. 5 that the "doping-strips" have serrated edges, the object being to give greater adhesion and to prevent peeling off.

Doping patches, which are used where small holes or windows are required, are applied in a similar manner.

We are indebted to Messrs. Handley Page Ltd. for facilities for staging this series of photographs.

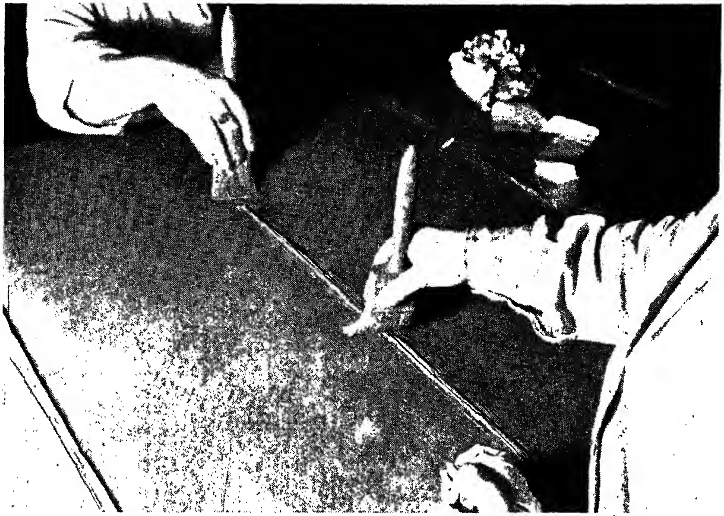


Fig. 2.—AFTER "STRINGING" HAS BEEN COMPLETED THE WORK IS GIVEN A COATING OF RED DOPE WHICH TAUTENS THE FABRIC. SEAMS AND LINES OF "STRINGING" THEN RECEIVE AN ADDITIONAL COAT OF DOPE.

Fig. 3.—STRIPS OF FABRIC ARE THEN LAID ON THE STILL TACKY DOPE AND RUBBED DOWN.

Fig. 4.—THE STRIP IS RUBBED DOWN UNTIL THE DOPE BEGINS TO OOZE THROUGH.
It is then given a final coat of red dope, producing a strong watertight seal.

Fig. 5.—THE FABRIC "DOPING STRIPS."
Note the serrated edges to give greater adhesion and to prevent peeling off.

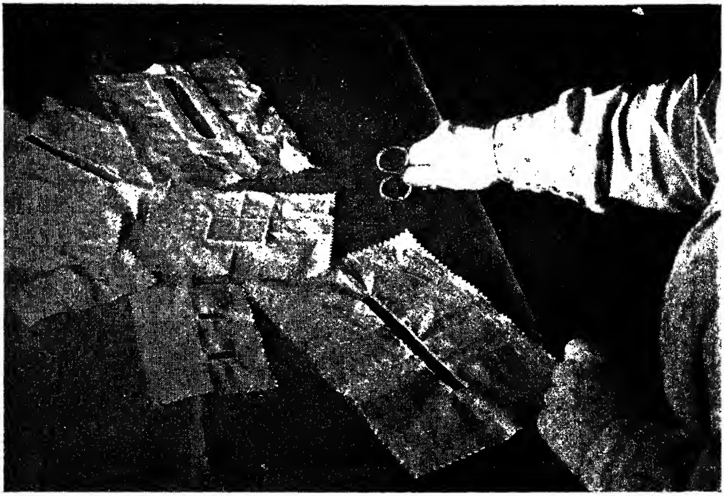


Fig. 6.—WHERE SMALL HOLES OR WINDOWS ARE REQUIRED THESE ARE MADE BY USING "DOPING PATCHES."

The operator is here seen burnishing the edge of a hole or slot underneath the fabric to facilitate accurate location of a patch.

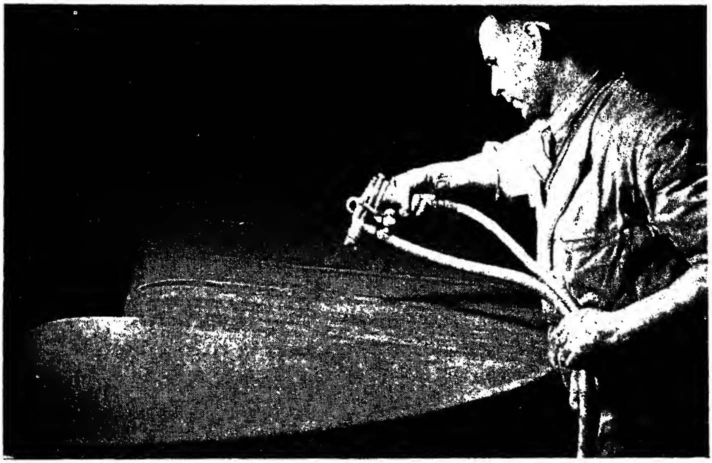


Fig. 7.—THE FINAL OPERATION.

The fabric is sprayed with a non-tautening paint, of the desired colour.

PATCHING FABRIC

REPAIRING SMALL TEARS IN THE FABRIC COVERING OF AEROPLANE PARTS

SMALL tears in the fabric covering of aeroplane parts can usually be repaired by patching in the following manner.

The dope should first be removed from the fabric surrounding the tear with dope solvent.

A fabric patch of suitable size is then prepared with its edges serrated or, preferably, well frayed.

Applying the Prepared Patch

The fabric surrounding the tear from which the dope has been removed is then redoped and the prepared patch is thoroughly doped, laid over the tear and smoothed down with a doped pad or a wad of doped fabric (Figs. 1 and 2).

The Finishing Coat

When hard and dry, the patch is redoped (Fig. 3), and when this second coat of dope is dry the finishing coat of pigmented dope is applied to the repair (Fig. 4).

Large Tears

Large tears may require the removal and replacement of the portion of fabric covering affected, but if not unduly extensive they may be patched in the manner described above, the edges of the tear being stitched together lightly with a herring-bone stitch, after removal of the dope and before putting on the patch.

The thread used for stitching the edges of such tears together should be of weight suitable in relation to the weight of the fabric.

We are indebted to Messrs. Airwork Ltd., of Heston, for facilities for staging the accompanying photographs.

Fig. 1.—THE AREA AROUND THE TEAR IS REDOPED AND THE DOPED PATCH PLACED OVER THE TEAR.

Fig. 2.—THE EDGES OF THE PATCH ARE CAREFULLY RUBBED DOWN.

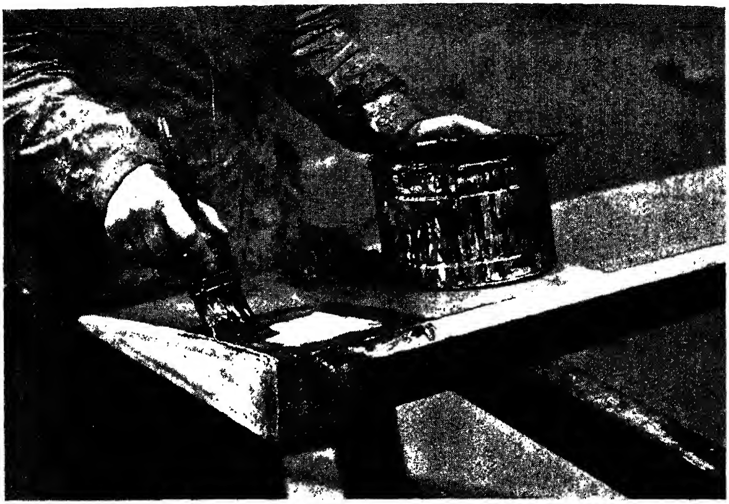


Fig. 3.—WHEN DRY THE WHOLE PATCH IS REDOPED.

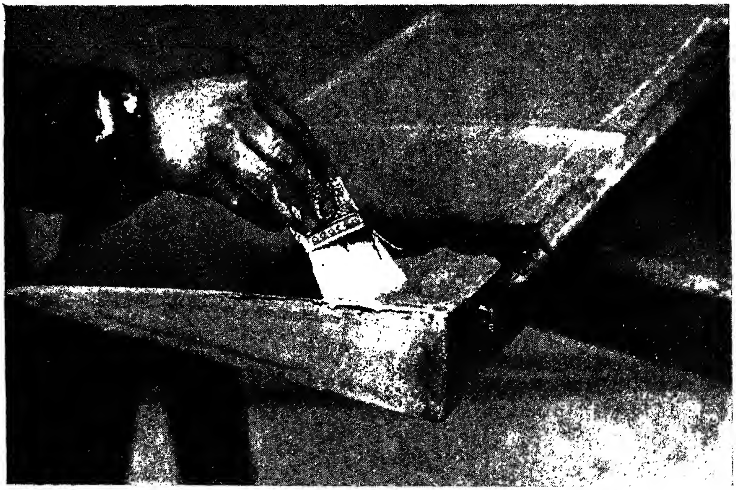


Fig. 4.—THE FINISHING COAT OF PIGMENTED DOPE IS APPLIED.

AIRSCREW DEVELOPMENT AND MATERIALS OF CONSTRUCTION

By A. C. Clinton, A.F.R.Ae.S.

THE different types of airscrews may be made of various materials, of which there are five kinds in use at present. The materials used for construction are wood, steel, aluminium alloy, magnesium alloy, and synthetic resin used in conjunction with laminated wood or layers of specially woven fabric. The position as regards the choice of material and construction of airscrews is still in a state of change, since some of the materials require further development in order to prove their efficiency. A large proportion of airscrews are still made of wood, next comes aluminium alloy, and there is a small proportion made of magnesium alloy, steel, and compressed and impregnated laminated wood.

Wood originally formed the material for all airscrews; they were reliable, cheap to manufacture, they could be made easily by skilled labour and had the advantage of not giving trouble due to fatigue. Wood had the disadvantage, however, of being subject to distortion owing to climatic conditions, and was easily damaged by stones picked up from aerodromes, or by splashing water in the case of marine aeroplanes. Further, wooden airscrews, when damaged, are not easy to repair, and are usually scrapped.

Owing to the disadvantages of wooden airscrews, efforts were made to develop metal types, such as the hollow steel blade, built up of thin sheet, either riveted or welded together. These blades had a certain amount of success, but were liable to distortion and fatigue trouble. A more successful metal blade was that made of aluminium alloy; this was a solid thin blade, and was designed so as to be flexible, advantage being taken of the centrifugal forces to offset stresses due to the imposed bending moments. This blade had limitations, however, because it could not withstand high engine powers; a thicker and more rigid blade was necessary.

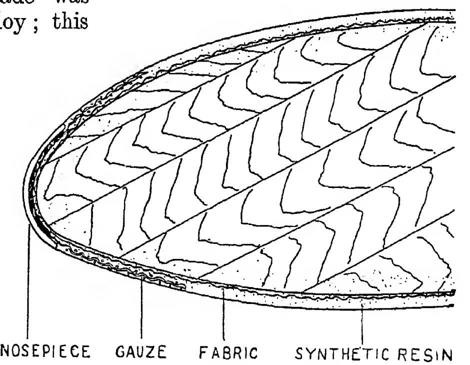


Fig. 1.—Schwarz blade section.

The aluminium alloy airscrews for increased engine powers were developed. They were of the detachable blade type, the blades being clamped in the hub and capable of being set at any desired pitch on the ground before locking. With the development of the variable pitch airscrews came a vast change in the method of design of hub attachments : the difficulty of holding airscrew blades securely in the hub, so that they would be satisfactory under the high centrifugal loads and bending moments, and at the same time be free to rotate, was considerable. The airscrew design went through various changes, and although blades of different material were tried, the development of aluminium alloy blades seems to have met with most success, the forging process being controlled so that the maximum strength is obtained at the root end of the blade giving good grain flow.

Magnesium has always been an attractive material owing to its lightness, but it was slow in being used due to failures, although when its properties were understood better, the results which followed showed that it was a promising material.

Laminated, impregnated and compressed wood is a material generally well suited for airscrew blades, embodying the advantages of a wooden airscrew without the disadvantages.

Reinforced synthetic resin blades have been made and used on various types of engines, and with the improvement in manufacture and materials, they should take their place as an accepted approved material.

Wooden Airscrews

Wooden airscrews are built up of several laminations of hard wood. They are not difficult to manufacture, and owing to the improvement of the type of adhesive for the laminations, they have a marked advantage over the earlier types which used hot hide glue.

Wood is cheap and light and in these characteristics is superior to other materials. The blade sections of a wooden airscrew, while thicker and better for take-off and climb, are not so good at high speeds as the metal type. Another useful point about wood is that it can be worked easily and accurately, so that it is a simple matter to make several airscrews of alternative designs from which the best may be selected. In the case of the detachable metal blade made from a forging, the variations of which are limited, the designer cannot have so great a choice of finished shapes.

Wood is a good absorber of vibration and does not suffer from fatigue, important qualities for dealing with torque variations of an engine, and it is superior to metal in these respects.

It is difficult to protect natural wood against climatic changes and abrasion, but by means of fabric covering a blade can be reasonably protected from moisture, and a metal sheathed leading edge is some protection against grit, rain and spray.

In more recent years, the blade has been better protected by coating

it with a special synthetic resin, by means of the Schwarz process. This process consists in covering the airscrew completely with a film of synthetic resin (cellulose acetate). The leading edge is covered with a thin strip of cellulose material, and the whole of the blade and boss is covered with a layer of fabric or high tensile steel gauze according to the duty required from the airscrew. The leading edge is covered with a strip of phosphor bronze wire gauze on which is a brass nosepiece. The final plastic covering of cellulose acetate is applied soft and the airscrew is then placed in a special container and subjected to high pressure. The coating enters the pores of the wood ; it is hard, non-corrosive, resists abrasion, and hermetically seals the airscrew. A high polish can be given to the surface, thus improving the efficiency of the blade by reducing drag. A section of a Schwarz blade is shown in Fig. 1.

By means of impregnating and compressing the wood at the blade root and fitting this with a steel sleeve, it is possible to make detachable blades suitable for use in a fixed pitch or variable pitch type of hub.

In the table which follows are given the properties of mahogany compared with compressed and impregnated wood.

TABLE I

MAHOGANY

In Tension

Ultimate strength	12,000 to 20,000 lbs. sq. in.
Limit of proportionality	5,000 to 10,000
Young's modulus	$1{\cdot}4$ to $1{\cdot}8 \times 10^6$

In Compression

Ultimate strength	6,000 to 8,000 lbs. sq. in.
Limit of proportionality	Approx. 3,000
Specific gravity	0·52

COMPRESSED AND IMPREGNATED WOOD

In Tension

Ultimate strength	32,500 lbs. sq. in.
0·1 per cent. proof stress	26,000 ,, ,,
Limit of proportionality	7,500
Young's modulus	$3{\cdot}85 \times 10^6$

In Compression

Ultimate strength	23,000 lbs. sq. in.

In Shear

Across grain	15,000 lbs. sq. in.
Along grain	4,000 ,, ,,
Specific gravity	1·4

Fig. 2.—REED AIRSCREW—TWO-BLADE.

Another method of giving wooden blades a hard resin finish has been developed by the B.T.H. Company and the Hordern-Richmond Aircraft Company. In this process the blade is dipped in resin and a resin-soaked stocking is drawn on and covered with a rubber sheath. The blade is then surrounded by fine shot and put in a press and "cooked" at approximately 80° F. for about twenty minutes, during which the stocking and resin coating become intimately bonded with the wood. The leading edge of the blade can be reinforced in a suitable manner to resist abrasion.

Aluminium Alloy Airscrews

The first type of metal airscrew to achieve much success was made of aluminium alloy and, as already mentioned, had a thin type of flexible blade, which in flight set itself closely along the direction of the resultant forces, thus reducing the bending moment. (Fig. 2 shows a two-blade Reed air-screw.)

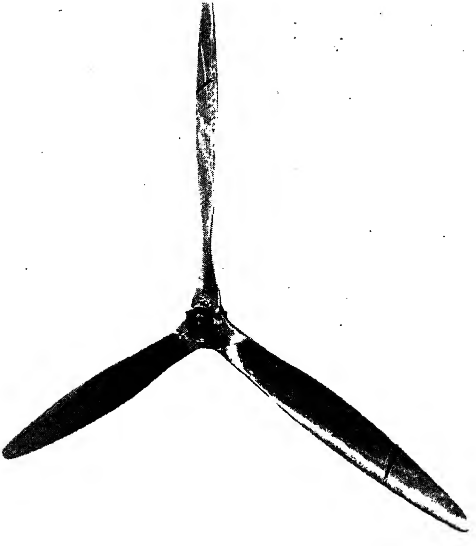


Fig. 3.—FAIREY-REED THREE-BLADE AIRSCREW.

It should be noted, however, that unless this material is perfectly homogeneous, and the blades are of exactly the same dimension, the deflections may be unequal. Vibration is, therefore, liable to be set up, due to unbalanced moments, and it is necessary to have special dynamic balances for checking the blades. The

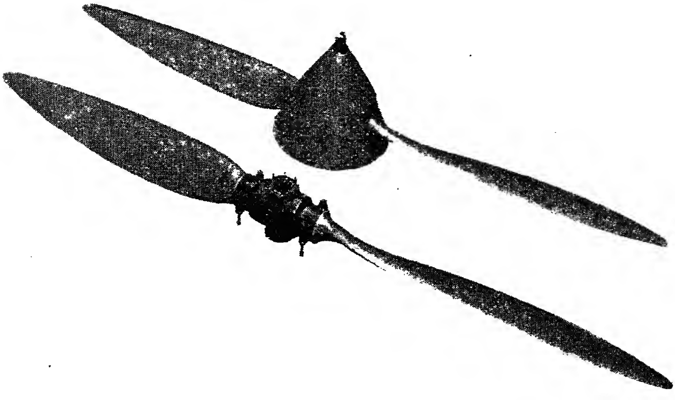


Fig. 4.—ALUMINIUM TWO-BLADE AIRSCREW.

three-blade Fairey-Reed airscrew, Fig. 3, is made from a light alloy forging which is machined and then twisted to the required pitch.

While thin sections are useful for high speed, they tend to lose thrust at low speeds because of lower maximum lift and earlier stalling of the blade, and it is not easy to overcome the manufacturing difficulties involved in the design of airscrews which combine the necessary aerodynamic qualities and flexibility.

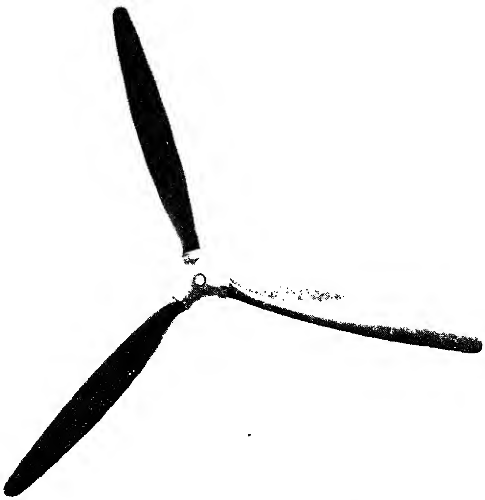


Fig. 5.—ALUMINIUM THREE-BLADE AIRSCREW.

Following the Reed type came the detachable blade machined

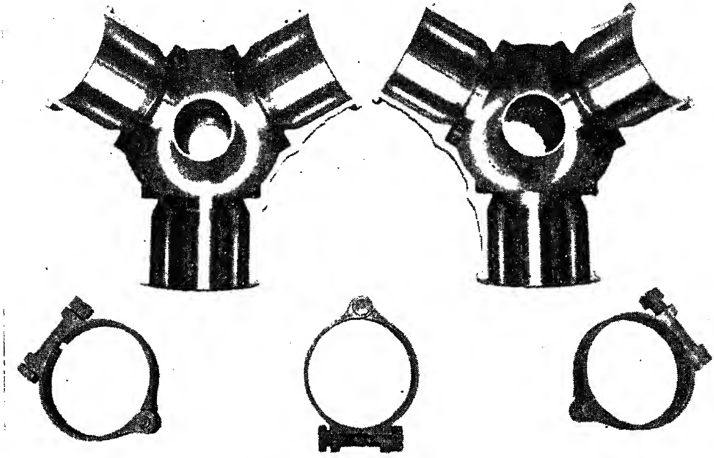


Fig. 6.—HUB FOR THREE-BLADE AIRSCREW.

from a forged blank. These blades are designed for interchangeability with engines of similar power range. A two-blade design is shown in Fig. 4, and a three-blade type in Fig. 5, while Fig. 6 shows the two-piece three-blade hub with clamping rings.

In the development stages of the detachable blade some failures occurred due to fatigue, and it was found that the cause could generally be traced to that part of the blade where the aerofoil shape changes section to the cylindrical root. By careful blending of the blade into the root the trouble was overcome and in addition great care was given to the forging of the blade blank so that correct grain flow was obtained (Fig. 7).

The fitting of the blade root in the hub must be quite accurate and special attention must be given to any dents, corrosion or pitting which might be the cause of the initiation of a small fatigue crack.

Aluminium alloy blades are anodically treated for protection against corrosion, and are cleaned with lanoline during service.

Metal blades do not have such a good aerofoil section close to the root as wooden types, with the result that around the centre of the airscrew disc the slipstream for cooling the engine is rather slight; consequently, aircooled engine designers have had to deal with the problem of air cooling by means of a specially developed cowling.

Duralumin airscrews are suitable for engines ranging in power from

100 to 2,000 h.p. with diameters varying from $5\frac{1}{2}$ ft. to 16 ft., while weights vary from 60 lbs. to 600 lbs.

The following table gives the properties of suitable aluminium alloys.

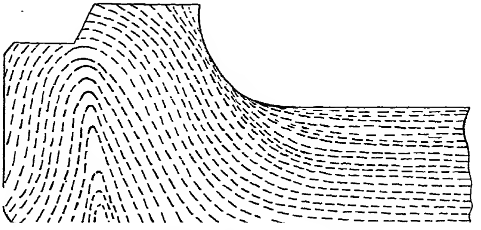


Fig. 7.—GRAIN FLOW IN BLADE ROOT.

TABLE II

DURALUMIN. SPECIFICATION D.T.D.150

Copper .	3·5 to 4·5 per cent.
Magnesium	0·4 to 0·7 ,,
Manganese	0·4 to 0·7 ,,
Remainder	Aluminium
Iron .	0·75 per cent. (maximum)

Properties

0·1 per cent. proof stress . .	13·5 tons sq. in.
Maximum stress . . .	22·5 ,, ,,
Elongation, per cent. on 2 in. .	15

HIDUMINIUM. RR56. SPECIFICATION D.T.D.184

Copper	1·5 to 3·0 per cent.
Nickel	0·5 to 1·5 ,,
Magnesium	0·4 to 1·0 ,,
Iron	0·8 to 1·4 ,,
Titanium	0·02 to 0·12 ,,
Silicon	1·0 per cent. (maximum)
Remainder	Aluminium

Properties

0·1 per cent. proof stress . .	20 tons sq. in.
Maximum stress . . .	27 ,, ,,
Elongation, per cent. on 2 in. .	10

Steel Airscrews

Various attempts have been made to use steel for airscrew blades, the development covering both solid and hollow types. In spite of many experiments little progress has resulted with the solid blades owing to the weight factor, but some success was achieved with the hollow blade type, shown in Fig. 8. The two-piece hub is given in Fig. 9.

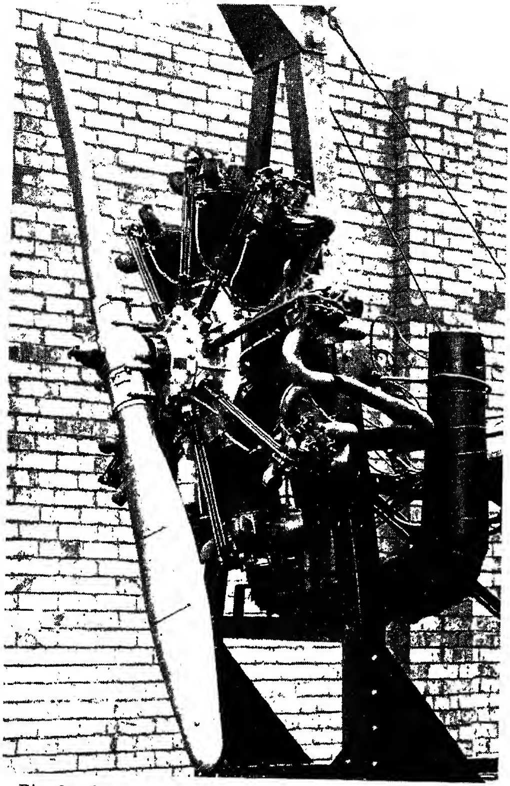


Fig. 8.—LEITNER WATTS TYPE HOLLOW STEEL AIRSCREW.

The hollow blades were made from mild steel which was satisfactory for working and welding. The blade consisted of two pressings back and front, welded at the leading and trailing edge, and they were built up with internal laminæ as shown in Fig. 10, the first one being approximately three-quarters of the radius, and the others varying in length according to design requirements. It should be noticed that the laminæ were forked to avoid any sudden change in stress, an important point in airscrew design and one which must be carefully watched, especially where the aerofoil shape of the blade changes to the cylindrical hub root. The hollow blades were fitted with inner and outer sleeves at the root, these being welded to the laminæ (Fig. 11).

The manufacture of steel blades did not present any difficulty, but they have not succeeded, however, owing to their liability to fatigue causing failures near the root or near the tip due to resonant vibrations of the thin wall. In spite of the searching bench test, trouble was experienced after some hours of flying and further development is necessary to make the steel blade reliable. Although there are possibilities of steel blades being used for medium powered engines, it does not appear at present that they will be practicable for high power engines, as apart

Fig. 9.—HUB FOR STEEL AIRSCREW.

from material and design features there is the question of weight compared with the light alloy materials.

Magnesium Alloy Airscrews

Owing to its lightness magnesium has always been an attractive metal for airscrews, but in the development stages failures occurred and retarded progress. The forging technique of magnesium has been steadily improved so that good grain flow may be obtained, and the liability of the metal to corrosion has been countered by effective protective treatment.

In the early stages magnesium airscrews were designed on the same lines as those of aluminium alloy, but with rather uncertain results, and, as the result of development tests, it was found that when using magnesium bigger scantlings must be used, and that it does not pay to take the maximum advantage of the lower specific gravity. Having achieved success with blade design, a certain amount of trouble was found in the hub due to fatigue and fretting, but this was overcome by using a synthetic fabric bush between the blade root and the hub, together with a better form of screw thread for reducing the effect of stress concentration. Details of the blade root are given in Fig. 12 and show the tapering synthetic resin bush and the screw thread.

Protection against corrosion is obtained by means of chromate treatment which, however, is not proof against abrasion. The blades should be kept coated with a film of lanoline which protects any exposed parts.

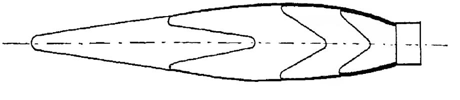


Fig. 10.—STEEL AIRSCREW BLADE LAMINÆ.

It is possible that by improving the magnesium alloy, better anti-corrosion properties will be obtained, but until this matures, attention to surface protection is still required and for

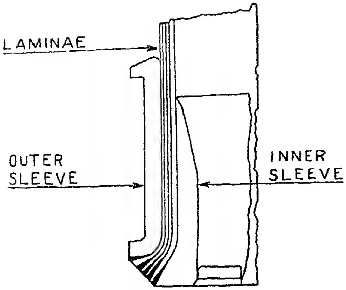


Fig. 11.—STEEL AIRSCREW ROOT.

this the synthetic resin products offer some promise. Fig. 13 shows a three-blade airscrew and Fig. 14 one of the detachable blades. One of the latest types of three-blade airscrew is shown in Fig. 15. It is suitable for a 1,000-h.p. engine and weight 344 lbs., having a diameter of 12 ft. 8 in.

A specification of magnesium alloy used for airscrews is as follows :—

TABLE III

Aluminium	11·0 per cent.
Zinc .	2·0 ,,
Manganese	1·0 ,,
Magnesium	Remainder

Properties

0·1 per cent. proof stress	10 to 12 tons sq. in.
Maximum stress .	18 to 20 ,, ,,

Laminated and Compressed Wood Airscrews

Although wood as an airscrew material had certain advantages, it has been mentioned that the disadvantages caused attention to be given to metal construction; however, the idea of protecting wood so that it could overcome trouble due to climatic changes and abrasion has been studied for many years with the result that this natural material is becoming important.

By means of synthetic resins a greatly improved adhesive has been obtained for joining the natural wooden laminations, and these may in some processes be impregnated by a suitable resin before being joined. These two methods produce wooden airscrews with laminations bonded by an adhesive unaffected by moisture or an impregnated airscrew much denser and stronger than natural wood. Further, since the degree of resin impregnation can be controlled, it is possible to have the density of a blade varying from the root to the tip.

Airscrew blades for low and medium power engines may be made in one piece, while for high powered engines separate blades can be made suitable for use with fixed pitch or variable pitch hubs. In the case of detachable blades, the root is fitted with a pressed-on steel sleeve.

In one method of construction the blade is made of laminated light wood, scarfed by an interrupted series of long spliced joints to a root

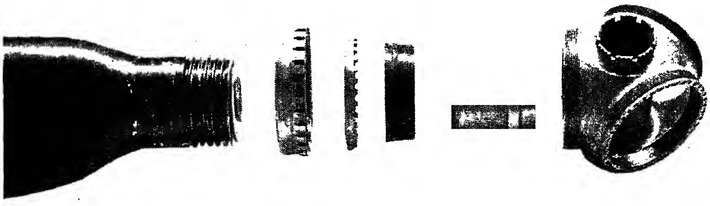


Fig. 12.—DETAILS OF ROOT FITTING OF MAGNESIUM BLADE.

block of laminated resin impregnated and compressed hard woods, which may be interleaved with fabric.

This method of construction is well suited to meet the variation in stress requirements of a blade where at the tip it is necessary to have good notch resistance and low specific gravity, at the centre good bending and tensile strength, while at the root tensile strength combined with resistance to shear and shock are essential.

A Schwarz compressed wood airscrew is shown in Fig. 16.

In the following table, a comparison is given between a high-grade reinforced timber and a high tensile aluminium alloy.

TABLE IV

	Reinforced Timber.	Aluminium Alloy.
Specific gravity . .	1·4	2·8
0·1 per cent. proof stress	10·5 tons sq. in.	28 tons sq. in.
Maximum stress .	20 ,, ,,	33 ,, ,,
Young's modulus .	4×10^6	10×10^6
Shear modulus . .	$0{\cdot}25 \times 10^6$	4×10^6

Reinforced Synthetic Resin Airscrews

While synthetic resin has the advantage of corrosion resistance, fairly good fatigue properties and good damping capacity, it has low values of elastic moduli and a liability to deform at relatively low stresses. For an airscrew blade to have the necessary stiffness it has to be fairly thick and when compared with metal blades there is not a great saving in weight. Blade strength may, however, be modified according to the kind of corded reinforcement used, and by arranging for the cords to follow the

Fig. 13.—MAGNESIUM AIRSCREW.

surface shape, great shear strength can be obtained in the root. The arrangement of the cords may be compared to the grain in a well-forged metal blade. By this method of construction a tensile strength of 69,000 lbs. per square inch has been obtained, and from destruction tests carried out it has been proved that this type of blade has a high factor of safety under running conditions.

A hollow moulded blade has recently been developed experimentally in which continuous lengths of fabric cord or sheet form have been used. The blade is moulded and compressed around a core of fusible metal accurately located in the centre of the blade ; the core is removed finally by heat without damaging the blade material.

The roots of the blades of this type are fitted with steel sleeves for use in fixed pitch or controllable pitch hubs.

Airscrew Material Development

Although the materials used for airscrews are chiefly wood and aluminium alloy, with magnesium alloy, and fabricated synthetic material accounting for a small proportion, the tendency is for natural wood to be replaced by the compressed and impregnated type, and for the aluminium alloy type to increase.

The improvement of the forging technique of magnesium alloy has increased the number of airscrews in use, and if further research developments result in improving its non-corrodibility qualities and its strength so that more advantage may be taken of its lightness, then it should replace a proportion of the aluminium alloy.

As the power of engines increases, larger diameter airscrews will be required, which means considerable increase in weight and a growing

Fig. 14.—DETACHABLE BLADE.

Fig. 15.—MAGNESIUM AIRSCREW FOR 1,000-H.P. ENGINE. Note improvement in hub design compared with Fig. 13.

Fig. 16.—SCHWARZ THREE-BLADE AIRSCREW (COMPRESSED WOOD BLADES) FOR GAUNTLET-MERCURY INSTALLATION.

demand for light material, and since synthetic resin materials have made much progress recently the moulded airscrew when further developed should replace a good proportion of metal airscrews.

THE USE OF PLASTICS FOR AIRCRAFT

By A. C. Clinton, A.F.R.Ac.S.

THE word plastics is applied to certain plastic materials which are used to make a variety of articles also called by the generic term plastics. The plastic article is formed from a synthetic or natural resin material by the application of pressure or heat or a combination of these, and its finished shape is fixed, being determined by a mould.

Plastic materials cover a wide range of chemical compounds which can be divided into two groups: (*a*) thermo-plastic, and (*b*) thermo-hardening.

(*a*) Thermo-plastic material makes a finished article which undergoes scarcely any chemical change at normal moulding temperatures, and it can be repeatedly heated and cooled again without any apparent change in physical properties, at any given temperature.

(*b*) Thermo-hardening material makes a finished article which undergoes a chemical change due to the heat, and it cannot be changed from its finished hard form to a soft condition.

Material from group (*a*) or (*b*) is chosen in accordance with design requirements, and at the present time there is a large number of materials from which to choose. These materials can be used for many articles in aircraft engineering where wood and metal are now employed, but it is not inferred that plastics can just replace wood and metal. It is not merely a substitute for something else. There are many articles that could be made in plastics with advantage, because of the properties of lightness, resistance to heat, moisture, acids, oil and corrosion, or because of strength properties and damping characteristics and the ability to maintain a rigid shape.

For components which must withstand stress, plastics may be used, having due regard to their properties, which may frequently be of value in conjunction with metal or wood in some form of composite structure.

A list of the main types of plastics is given later, and it will be seen that there is a good number from which to choose. The suitability of the material must be carefully examined for the work in hand, and consultation with the supplier is advisable where new applications are anticipated.

Plastics may be considered for use under three headings:—

1. Moulded with or without the addition of organic or inorganic fillers.

The plain synthetic resin has many uses in the form of knobs, handles, small instrument cases, and parts which are not stressed to any extent.

Such materials tend to be brittle under tension, they have a tensile strength of the order of 5,500 lbs./square inch, but this figure may be increased according to the amount of filler used. Wood flour is a satisfactory filler for many purposes, but if increased heat resistance is required, then inert mineral fillers are used. Mineral fillers increase the water resistance.

2. Moulded with the addition of reinforcement, such as corded material.

By reinforcing the synthetic resin with fabric or cord, considerable improvement in strength characteristics may be obtained, and, according to the type and method of arranging the reinforcement, tensile strengths up to 60,000 lbs./square inch may be obtained. When a material is designed for maximum tensile strength, then its shear strength will be comparatively low, but a higher shear stress can be obtained at the expense of the tensile—*e.g.*, 60,000 lbs./square inch tensile would give approximately 2,500 lbs./square inch shear, and 10,000 lbs./square inch tensile would give approximately 6,000 lbs./square inch shear.

The strength properties, which vary so much according to the kind of reinforcement and quantity of resin used, while giving some choice of material, emphasise that it must be studied carefully before being incorporated in a design. Fabric fillers give greater strength, but have a low water resistance.

3. Impregnation of laminated and compressed wood.

Wood may be treated with synthetic resin by coating, and impregnation to give increased strength and other properties which are attractive for aircraft use. When the wooden veneers are compressed and impregnated a dense material results, which has useful applications for airscrews, struts, and other stressed parts.

Thermo-plastic Group

(*a*) *Natural Resins.*
- 1. Animal—shellac.
- 2. Vegetable (dammar gum ; rosin).
- 3. Mineral—bitumen.

(*b*) *Cellulose Plastics.*
- 1. Cellulose nitrate.
- 2. Cellulose acetate.
- 3. Ethyl cellulose.
- 4. Benzyl cellulose.

(*c*) *Acetylene Derivatives.*
- 1. Acrylic.
- 2. Vinyl.
- 3. Styrene.

(*d*) Casein.

Thermo-hardening Group

(*a*) Phenol-formaldehyde.
(*b*) Urea-formaldehyde.
(*c*) Alkyd.

Other Types of Resins

(*a*) Rubber Group.
- 1. Rubber.
- 2. Synthetic rubber.
- 3. Rubber derivatives.

(*b*) Aldehyde resins.
(*c*) Cumarone and indene resins.
(*d*) Aniline resins.
(*e*) Ketone resins.
(*f*) Numerous other resins.
- 1. Organic.
- 2. Inorganic.

Thermo-plastic Group

Shellac is a product made by refining the natural lac obtained from insects ; it has a tenacity and resiliency greater than the synthetic resins, and it is now used chiefly for making gramophone records.

Shellac is particularly useful for intricate shapes, it has a good surface, good electrical resistance and low water absorption. Shellac and some of the vegetable gums have been used for many years for making compositions and moulded designs, but as demands exceeded the natural supply, various synthetic resins have been developed.

Bitumen is particularly suitable for moulding, and since it is unaffected by acid and is non-absorbent, is useful for battery boxes. It can be compounded with a variety of fillers such as mineral dust, asbestos, and cotton fibre.

There are various kinds of bitumen, but all have the same general qualities, a wide range of electrical insulators and other parts can be made having properties varying according to the type of filler used. Greater variation in the properties may be obtained by mixing with rubber and the phenolic resins. Bitumen mouldings are made by Ebonestos Insulators Ltd.

Cellulose nitrate is one of the earliest plastics used commercially, and when mixed with camphor makes the familiar celluloid, in which form it can be made into a wide variety of articles. Xylonite and Pyroxylin are other names for this material.

The specific gravity varies from 1·35 to 1·6, it has a tensile strength of 5,000–10,000 lbs./square inch, and modulus of elasticity of 200,000–400,000 lbs./square inch.

Cellulose acetate is similar to cellulose nitrate, but has the advantage of being non-inflammable, and appears under the names of Cellastine, Bexoid and Erinofort.

Cellulose acetate is suitable for injection moulding ; in this process the heated plastic is forced into a cold mould in which it sets, and can then be removed at once. Instrument panels and instrument dials can be moulded in this manner. Any metal inserts for fastenings, and housings for instruments, switches, etc., can be included in the mould.

A useful material can be obtained by compounding cellulose acetate with a special barium mix, which gives the finished article the property of luminosity so that it is visible in the dark. This material is useful for instrument and control panels, instruments, controls for engine, electrical systems, gun and gun turrets, navigational instruments, instruction plates, bomb controls and sights, and emergency exits.

Cellulose acetate has a specific gravity of 1·27–1·63, a tensile strength of 3,500–10,000 lbs./sq. in., modulus of elasticity of 200,000–400,000 lbs./square inch, and a compressive strength of 11,000–16,000 lbs./square inch.

Benzyl and Ethyl Cellulose are not made direct from cellulose, but are developed by a process which includes treatment by benzyl or ethyl

chloride. Benzyl cellulose is manufactured as a moulding powder and may be used like cellulose acetate for extrusion or pressure moulding. It resists water absorption and chemical attack better than the acetate, and therefore has a wider range of application.

There are three useful plastics obtained from acetylene. Of the acrylic type there is methyl methacrylate, which makes a clear glass-like moulding, and, according to the dye, and/or kind of filler which may be used, so the moulding may be coloured and rendered opaque or translucent to meet requirements. Material of this kind is produced by Mouldrite Ltd., and called Diakon. Diakon resists most chemicals, and has a very low water absorption; it is, therefore, useful for batteries, instruments, and visual flow gauges.

A similar type of this material is marketed under the name of Perspex by I.C.I. Ltd., in the form of sheets and rods, which can be machined. In the sheet form it is useful for windows which have to conform to some aerodynamic shape, such as cockpit coverings and gun turrets.

Perspex is one of the most useful organic "glasses" since it is lighter than other forms of transparent materials, the specific gravity being 1·19 compared with 1·35 of similar resins. It has a low moisture absorption, does not shrink or warp with age or exposure, is rigid in rounded or flat sheet form, and does not become brittle at very low temperatures. The fact that Perspex retains its strength under varying conditions of shape and temperature enables it to be used in a variety of curved forms without any supporting structure, and makes it attractive for aircraft work.

The following table gives some of its properties :—

Tensile strength at 20° C.	71,680–87,360 lbs./square inch.
Shear stress at 20° C.	89,600–94,080 lbs./square inch.
Compression strength at 40° C. . .	32,480 lbs./square inch.
Modulus of elasticity	$4{\cdot}48 \times 10^5$ lbs./square inch.

The Vinyl type produces transparent or filled mouldings, and it can be obtained in sheet, rod or tube form. It is practically unaffected by water, which quality makes it useful for outdoor application. Vinyl lacquers, adhesives and solutions for the treatment of fabrics are most useful, being waterproof and non-inflammable. It makes a tough and elastic form of organic glass which has less expansion and contraction than ordinary glass and has greater strength and transparency; it has a higher water absorption than some glasses and is softer. Since it can be easily moulded it is used in aircraft and motor cars, and development work shows that it should be useful for making optical lenses.

Styrene is a liquid which has recently been developed for commercial use, and it produces transparent or filled mouldings like the other synthetic resins and has similar properties, although its electrical properties are better than any other resin. Styrene is marketed under the name of Trolitul by F. A. Hughes & Co. Ltd.

The specific gravity is 1·05–1·07, tensile strength 5,500–7,500 lbs./square inch; modulus of elasticity 460,000–510,000 lbs./square inch, and compressive strength 13,000–13,600 lbs./square inch.

Casein plastics are the only type produced from milk, and an essential ingredient in their composition is water. The casein material is produced in extruded and sheet form, and while it can be moulded into its final form, it is usually machined from the sheet, tube or rod. Since the qualities of casein are liable to vary according to the moisture content, it is not so useful for aircraft work as some of the other plastics which can comply with exacting specifications. It appears under the trade names Lactoid, Galalith, or Erinoid.

Casein has a specific gravity of 1·35, a tensile strength of 7,600 lbs./square inch, and modulus of elasticity of 510,000–570,000 **lbs**./square inch; these figures are liable to variation due to the moisture content of the specimen.

Thermo-hardening Group

In the thermo-hardening group the two main types are the phenol-formaldehyde resins and the urea-formaldehyde resins, derived from coal, air and water.

The Phenol type is water and acid resisting, and may be used in powder form for moulding or in liquid form for impregnating paper, fabric or asbestos sheet.

Phenol resins can be used for a variety of articles forming the equipment, fittings and light structure parts of an aeroplane. These resins can be used in oil varnishes, paints and enamels, which are particularly good for resisting varying weather conditions, and it is hoped that improvement will be made in the varnishes for painting the underwater parts of the hulls of flying boats to prevent the growth of barnacles.

It appears under the names Bakelite, Mouldrite, Elo, Nestorite, Rockite, Indurite.

The table gives a comparison of properties when different fillers are used.

	Phenol Formaldehyde Compound.		
	Wood Flour.	Mineral.	Fabric.
Specific gravity . . .	1·34–1·52	1·70–2·09	1·37–1·40
Tensile strength, lbs./sq. in. .	6,000–11,000	5,000–10,000	6,500–8,000
Modulus of elasticity, lbs./sq. in. $\times 10^5$	10–15	10–45	7–12
Compressive strength, lbs./sq. in.	16,000–36,000	18,000–36,000	20,000–32,000

Urea type resins have properties and uses generally similar to those of the Phenol type, but, in addition, they have the important property of

being far more resistant to light and are able to produce light-coloured and light-fast materials for moulded or laminated work; they are useful for impregnating fabrics. The trade names are Beetle, Scarab, Pollopas and Mouldrite.

Alkyd resins are used chiefly for decorative purposes, and are not of much interest for aircraft use at present.

Natural Rubber

Rubber is the earliest form of plastic material used in aircraft. Natural rubber from latex vulcanised with sulphur has been used since the pioneer days for tyres, shock absorbers, and so on; for some years little change took place, but as developments in compounding and manufacture proceeded, the properties of rubber have improved to give good resistance to wear and increase in tensile strength.

An interesting development is "conducting" rubber. Rubber is normally a good non-conductor of electricity, but by means of compounding a special carbon black in the rubber mix it is possible to make it a conductor. The application of this conducting property is used for tail wheels, enabling the aeroplane to be earthed immediately it touches the ground.

Development in the compounding of rubber has increased its use in various forms of shock absorbers, an interesting application being that of engine mountings which need careful design in order that vibration may be dissipated without allowing any undue movement of the engine itself.

Rubber can be bonded to metal satisfactorily, and this has further increased its application since it becomes possible for it to be used under compression, tension or shear with freedom to distort without volume reduction.

Hard rubber or ebonite has been replaced to a great extent by synthetic resins, but it is still used for special insulation work, and also has application in its expanded cellular form.

Synthetic Rubber

Various materials have been produced coming under the general term synthetic rubbers, but actually these materials are new compounds having their own special properties and capable of being used for work quite unsuited to natural rubber.

Synthetic rubber resists sunlight, oil and heat to a much greater degree than natural rubber, and hence is useful for fuel hose, oil seals, hydraulic systems, engine mountings, washers, ignition cables and protective covering for metal components.

Thiokol and Neoprene are the two main types of synthetic rubber, both having the same general properties mentioned above. In addition, Thiokol resists aromatic solvents, while Neoprene is non-inflammable, and when put in a flame it only chars where touched. Neoprene is easy

to bond to metals, and is not much affected by ultra-violet light, which property is useful where rubber articles are exposed.

Expanded Rubber

Expanded rubber, which is made by compounding rubber with an inert gas, is composed of a structure of minute rubber cells. The cellular structure varies in density from 3 lbs. to 7 lbs. per cubic foot, and has a low water absorption. Expanded rubber is not brittle and can be cut, moulded and shaped easily, but only during recent years has it been much used in aeroplanes for small parts, although it was known some time ago. This cellular material can be built into plywood panels, and other structures, and is of undoubted use in the manufacture of wood and plastic aeroplanes, and can be used in metal ones. Expanded rubber is marketed under the name of Onazote.

Onazote is useful for fairings, seaplane floats, small airscrews or auxiliary services, insulating cabins against noise and extremes of temperature, and for use as a filling between plywood sheets for wing or fuselage coverings.

Reinforced Wood

The use of synthetic resins in conjunction with wood has caused a revival of interest in this natural material and the building of an aeroplane with a plastic structure has been seriously proposed.

Wood is subject to variation due to climatic changes, and though it has high tensile strength it is low in compression. It is useful in spars, struts and airscrews where bending moments occur, and its elasticity is valuable. Wood, however, generally gave way to metal and its development was pursued only on a small scale.

By using a suitable synthetic resin, wood can be surface treated in such a way that it is really hermetically sealed, and thus protected from the influence of the atmosphere. Blocks of wood built up of laminations, and glued and surface treated with synthetic resin can be used for making various aircraft components such as struts, spars, airscrews, etc.

In addition to surface treatment the resin may be used for impregnating the cellular structure of the wood. Laminations after treatment with resin are pressed in heated dies and a very homogeneous "strengthened" wood results. Another method is to employ very thin laminations using the resin solely as a binder, then subject them to pressure and heat. This method does not require so much resin as the impregnation method, and can be adapted for making built-up blocks with local reinforcement where increased strength is required. To obtain this variation in strength the number of veneers is increased at the required place; these additional veneers make a local section of increased density suitable for taking fittings and withstanding a reduction in strength due to bolt-holes; local strengthening can also be used to meet bending and shear loads.

A good example of the use of local reinforcement is in the case of an airscrew blade in which the stress requirements are a maximum in the root end and decrease towards the tip. With a built-up wooden block it is easy to interleave the necessary number of veneers to give the required increase in strength to meet the tensile, shear and shock stresses at the root. This reinforcement must be carefully decreased so that there is no sudden change in sectional strength towards the centre of the blade where bending and tensile stresses have to be met.

Laminated and compressed wood varies in specific gravity from 0·8 to 1·4, and it is interesting to note the comparison in the table between a good quality reinforced wood and an aluminium alloy.

	Reinforced Wood.	Aluminium Alloy.
Specific gravity .	1·4	2·8
0·1 per cent. proof stress	23,520 lbs./sq. in.	62,720 lbs./sq. in.
Maximum stress .	44,800 lbs./sq. in.	73,920 lbs./sq. in.
Young's modulus .	4×10^6 lbs/sq. in.	10×10^6 lbs./sq. in.
Shear modulus .	$0·25 \times 10^6$lbs./sq. in.	4×10^6 lbs./sq. in.

In some types of reinforced material the wooden laminations are interleaved with fabric where local increase in strength is required.

Wood veneers can be impregnated by a special synthetic resin by the JIC process, and they can be curved to any kind of shape without the wood or resin cracking. There are several applications for this smooth surfaced material for aircraft, such as wing and fuselage covering, and for building up composite box spars. A strong light structure can be made by putting a layer of expanded material like Onazote between two sheets of JIC processed wood. JIC wood is waterproof and tough, and suitable for wing-tip floats.

Non-stressed Parts

Classed under the general heading of non-stressed parts there is a wide range of articles finding uses in all parts of the aeroplane equipment and structure. Some of these parts have already been referred to when dealing with the different types of synthetic resins.

One of the materials useful for non-stressed parts consists of phenolic resin with cellulose, cotton and fabric reinforcement; it is useful for control units and control pulleys, also for the bush fitted to the hub of adjustable pitch airscrews to provide secure locking and to prevent fretting between the blade and the hub. It has a specific gravity of 1·34–1·38, tensile strength 15,000–22,500 lbs./square inch, modulus of elasticity $1·0–1·5 \times 10^6$ lbs./square inch, and a compressive strength of 25,000–45,000 lbs./square inch.

Another kind of resin-impregnated fabric, Texolex, is used in control-

lable pitch airscrews for the purpose of preventing fretting between various metal parts; like similar materials it has good damping and strength properties.

A large variety of instrument cases are made in plastic materials which can be moulded with threaded portions for screw-on covers and with metal brackets, screwed inserts, etc., all ready to receive the mechanism.

The electric wiring system can be rendered much safer by using plastic insulation which is non-inflammable and unaffected by oil, fuel and heat, and, similarly, these properties suggest a much wider use of the appropriate plastic for the variety of plumbing systems, including oil and liquid cooling, oil and fuel systems, and the hydraulic system.

The equipment of a modern aeroplane requires a variety of articles in addition to what might be termed operational equipment; these include furnishings, decoration, eating and cooking utensils. All the items under these heads can be supplied from the existing range of plastics, which include among their useful properties resistance to attack by fungus and insects, which are troubles likely to be encountered in various countries.

Airscrews

Plastic materials have entered considerably into the development of airscrews, being used for (*a*) coating plain wooden blades, (*b*) impregnating and coating wooden blades, (*c*) moulded blades reinforced with fabric.

(*a*) The Schwarz process applied to ordinary untreated wooden blades protects the wood from climatic changes and abrasion, and gives a polished finish. The process consists of cellulose acetate resin applied to the blade after this has been covered with a layer of fabric or steel gauze according to the strength requirements of the airscrew. A Schwarz finish may be applied also to a blade whose laminations have been impregnated with resin and compressed.

(*b*) The laminations of the blade are impregnated with resin and compressed to form a dense material having many useful properties. The laminations may be interleaved with fabric, and additional veneers may be included at the hub end so as to form a dense and strong root to withstand shear and shock forces.

(*c*) Moulded blades reinforced with fabric and cord have been made for various installations, and have proved satisfactory, although on a weight basis they have little advantage over metal due to the thicker sections necessary to give stiffness. Recent developments in synthetic resins have enabled a hollow blade to be moulded, and this has a reinforcement of continuous lengths of cord or fabric conforming to the surface shape.

Wing and Fuselage

While it is interesting to speculate on the aeroplane constructed largely of moulded plastics and impregnated wood, it must be remembered

that a great deal of step-by-step development work is necessary to prove out the efficiency of plastics for making wings.

The shell type of construction so largely adopted for aeroplanes involves a stressed skin structure which is satisfactory in metal wings now that the technique has been developed. A wing must have a high factor of safety, it must be stiff enough not to deflect and must resist the tendency to twist under different conditions of loading, and, most important, it must be light.

Impregnated and compressed wood is particularly good in pure compression, but is not so good as regards proof stress; however, for spars and the general framework of a wing, reinforced wood is satisfactory. For the wing covering JIC wood is useful and may be used as a single skin or as a double skin with Onazote sandwiched between; the same method can be applied to the shell of the fuselage.

The wing surface may be made also from moulded plastic material with or without fabric reinforcement, the surface in this case being built up of sections.

A plastic consisting of cellulose thread impregnated with phenolic resin is a promising material for making moulded wings and the external surfaces of the fuselage. It would be suitable as well for cowlings which need to be stiff and able to absorb vibration and resist fatigue.

The properties of this material are as follows :—

Tensile strength	22,000	lbs./square inch.
Compression strength	22,500	"
Shear strength	7,000	"
Modulus of elasticity	$2{\cdot}1 \times 10^6$	"
0·1 per cent. proof stress . . .	12,500	"
Specific gravity	1·39	

As regards the framework of the wing, plastic material cannot be used merely to replace existing metal parts; difference in strength properties means that these parts must be shaped differently and bigger scantlings used. The internal structure of a wing must allow for the provision of fittings, control ducts, electric wiring and certain equipment; further, it must be easy to assemble and repair.

From the designers' point of view plastics need more development to improve torsional rigidity; to increase the resistance to fatigue; to improve creep resistance, and to decrease notch sensitivity. The further application of plastics for stressed parts depends on the standard of the above properties, which should improve as the manufacture of resins is better understood, and it is anticipated that more types of resins will be developed.

Considering that plastics may become a material of construction in the future it should be possible to mould various sections of the wing and fuselage in large units, provided that the numbers required were such as to make the expenditure on presses and moulds economical.

NAPIER "RAPIER VI." AIR-COOLED AERO ENGINE

THE rated power of the "Rapier" Series VI. engine is: 370 b.h.p. at 4,750 feet altitude, with maximum power 395 b.h.p. at 6,000 feet altitude. The engine is of the "H" type having four blocks of four cylinders each, two blocks vertical and two inverted. By use of this arrangement a small frontal area has been obtained.

ENGINE AND COMPONENTS

Cylinders

The sixteen air-cooled cylinders of this engine are 3½ in. (89 mm.) bore and 3½ in. (89 mm.) stroke, with a compression ratio of 7·0 : 1 and a total capacity of 538·8 cu. in. (8,830 c.c.).

Forgings are steel, machined all over; cylinder heads—containing inlet and exhaust passages, valves and valve actuating mechanism—are of aluminium alloy.

Fuel and Oil

Fuel consumption at maximum cruising conditions at sea-level is ·58 pt./b.h.p./hour. At maximum take-off conditions at sea-level, consumption is 33 gallons per hour; at maximum climbing conditions at sea-level, 29 gallons per hour; and at maximum power level flight conditions, 34 gallons per hour. (For consumption at economic cruising conditions, see graph diagram, Fig. 6.) Fuel conforms to A.M. Specification D.T.D. 230 (87 octane).

The fuel pump is fitted on the port side. The pump is of the gear wheel type (Napier), and is driven off the cross-shaft situated at the rear of the engine. A packing ring is provided on the driving shaft in order to prevent leakage of fuel, and a relief valve is incorporated in the valve. This latter is controlled by a light phosphor-bronze spring, adjusted in such a way as to ensure an adequate supply of fuel under all conditions.

Oil consumption at maximum climbing conditions and at maximum cruising conditions is from 6 to 10 pints per hour; at maximum power conditions it is 17 pints per hour.

Lubricating oil conforms to A.M. Specification D.T.D. 109, and is applied by high pressure to crankshaft journals, big ends and gudgeon-pins. For the high-pressure oil supply, an adjustable pressure relief valve is incorporated. Lubrication of the reduction gears is accomplished by oil projected on to the teeth from two jets fed by the high-pressure system. Oil from this system is passed through a reducing valve to supply a low pressure system which lubricates the rest of the engine. The escaping

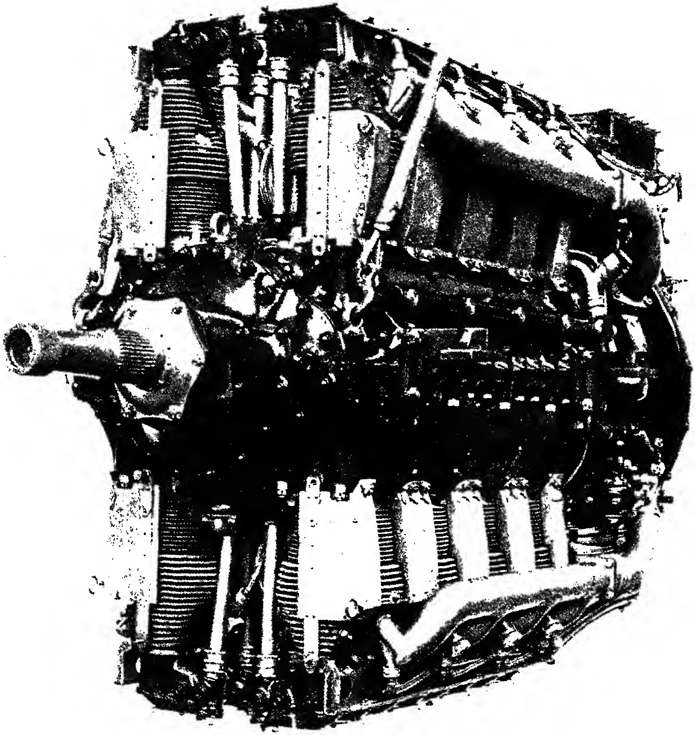


Fig. 1.—NAPIER "RAPIER VI." ENGINE.

oil from the various bearings, etc., is drained off into the oil sump and returned to the supply tank by scavenge pumps. The sump contains the oil pumps, the oil relief valves and the filters for the scavenge pumps. An adjustable pressure relief valve is incorporated for the high-pressure oil supply.

One pressure pump and two scavenge pumps are fitted in the "Rapier." The suction pumps scavenge the oil sump and return the oil to the supply tank. The pressure pump takes the oil from the supply tank and delivers it under pressure to the working parts of the engine.

Between the pressure pump and the engine is fitted a "Tecalemit" filter. Two filters for the scavenged oil are embodied in the oil sump of the engine, and these filter the oil before it enters the suction pump.

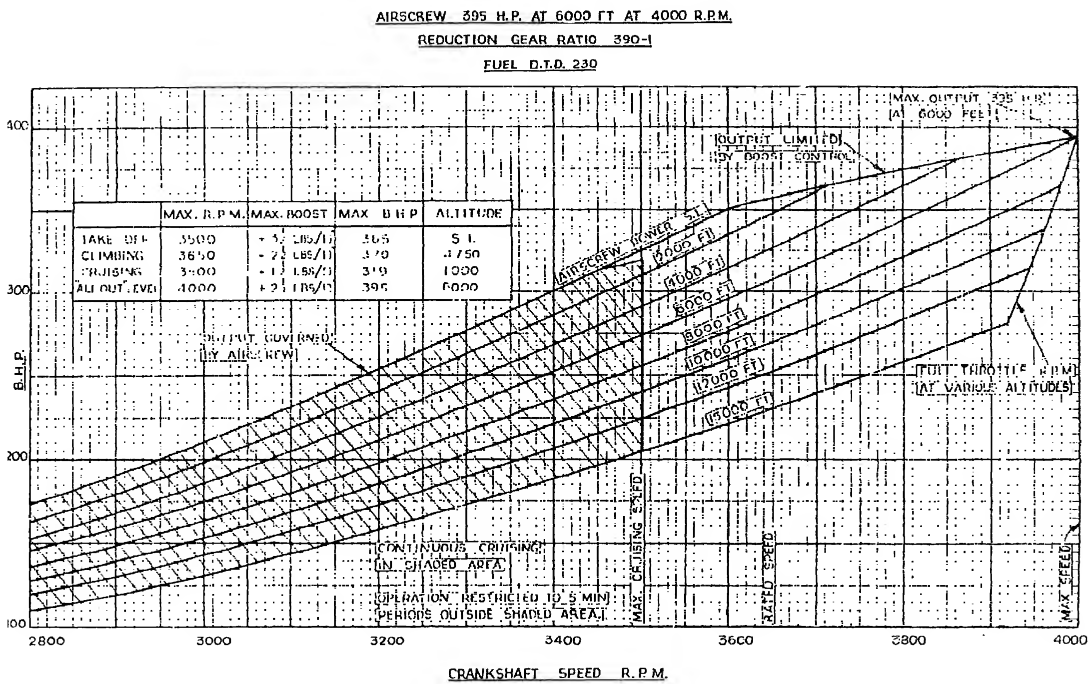


Fig. 2.—NAPIER "RAPIER VI."—POWERS AVAILABLE IN LEVEL FLIGHT.
Airscrew 395 H.P. at 6,000 ft. at 4,000 r.p.m. Reduction gear ratio ·390 : 1. Fuel D.T.D. 230.

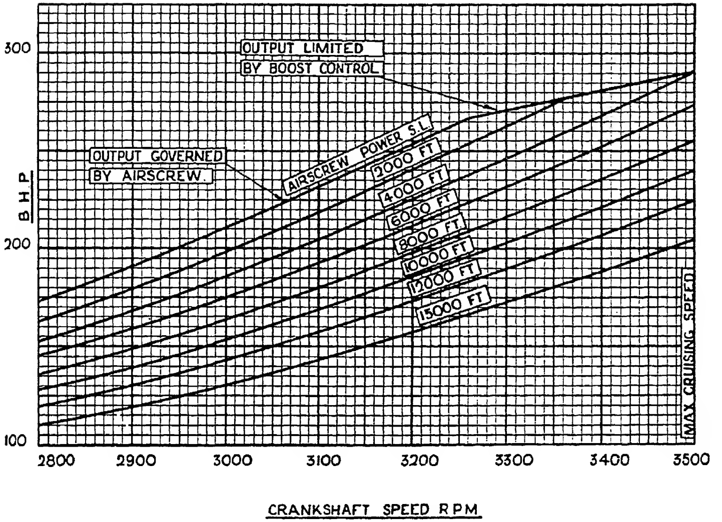


Fig. 3.—NAPIER "RAPIER VI."—POWERS AVAILABLE FOR ECONOMIC CRUISING ($1\frac{1}{2}$% R.P.M. DROP).

Max. economical cruising boost + ¾ lb./□″. Airscrew 395 H.P. at 6,000 ft. at 4,000 r.p.m. Reduction gear ratio ·390 : 1. Fuel D.T.D. 230.

Airscrew Shaft and Drive with Conditions and Powers at Sea-level

The engine is designed to accommodate a fixed pitch airscrew of wood or metal construction.

Viewed from the airscrew end, the direction of rotation of the airscrew is clockwise—that is, it is a Left-hand Tractor. The shaft is carried on two bearings. A ball-bearing to take the journal and thrust loads of the airscrew is fitted at the airscrew end of the shaft. The reduction between the airscrew shaft and the crankshafts is obtained through case-hardened spur gears ; the reduction gear ratio is ·390 : 1.

Cruising

The maximum conditions for economic cruising are at + ¾ lb. per square inch boost and 3,500 r.p.m. with $1\frac{1}{2}$ per cent. drop in r.p.m.

Maximum continuous cruising conditions at sea-level are 310 b.h.p. at 3,500 r.p.m. at + $1\frac{1}{2}$ lbs. per square inch boost.

The maximum take-off is 365 b.h.p. at 3,500 r.p.m. at + $3\frac{1}{2}$ lbs. per square inch boost at sea-level. The minimum take-off is 345 b.h.p. at 3,200 r.p.m. at + $3\frac{1}{2}$ lbs. per square inch boost at sea-level.

Maximum power at sea-level under climbing conditions is 350 b.h.p.

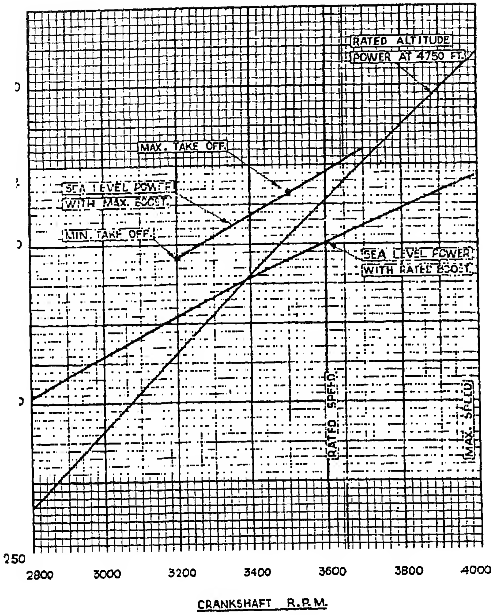


Fig. 4.—NAPIER "RAPIER VI."—POWER CURVES.

Based on Type Test Certificate No. N.R.24A. Reduction gear ratio ·390 : 1. Fuel D.T.D. 230.

	Max. r.p.m.	Max. boost.	Max. b.h.p.	Altitude.
Take off .	3,500	+ 3½ lb./	365	S.L.
Climbing .	3,650	+ 2½ lb./	370	4,750
Cruising .	3,500	+ 1½ lb./	319	1,000
"All out" level	4,000	+ 2½ lb./	395	6,000

at 3,650 r.p.m. at + 2½ lbs. per square inch boost.

The maximum all-out (five minutes) power at sea-level is 370 b.h.p. at 4,000 r.p.m. at + 2½ lbs. per square inch boost.

For T.V. dive the maximum r.p.m. at + 2½ lbs. per square inch boost is 4,800.

Supercharger

A supercharger of the centrifugal fan type is fitted at the rear of the engine. The impeller is driven from an extension of the airscrew shaft through layshafts by means of special spur gears. A friction disc clutch is fitted for protection against sudden changes in speed, and a Hobson automatic boost control unit is also fitted.

A special Napier Claudel-Hobson down-draught carburetter is fitted above the supercharger, and the body, which is of aluminium alloy, is oil-jacketed round the intake volute and the choke.

Starters and Pistons

Hand turning gear (Napier hand and gas starters) with induction priming and a gas distributor are both fitted. The hand turning gear has a ratio of 8·28 : 1 to the crankshaft, and has a clutch and ratchet fitted to prevent damage from backfires.

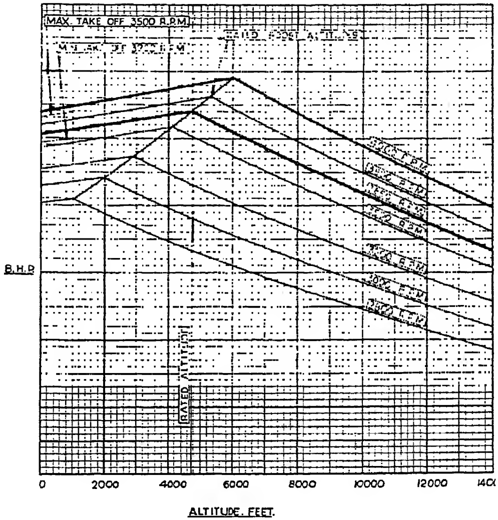


Fig. 5.—NAPIER "RAPIER VI."—PERFORMANCE AT ALTITUDE.

Based on Type Test Certificate No. N.R.24A. Fuel D.T.D. 230.

	Max. r.p.m.	Max. boost.	Max. b.h.p.	Altitude.
Take off .	3,500	$+ 3\frac{1}{2}$ lb./□″	365	S.L.
Climbing .	3,650	$+ 2\frac{1}{2}$ lb./□″	370	4,750
Cruising .	3,500	$+ 1\frac{1}{2}$ lb./□″	319	1,000
"All out" level	4,000	$+ 2\frac{1}{2}$ lb./□″	395	6,000

The pistons are of forged aluminium alloy. Each is fitted with two gas rings, one scraper ring and a hollow gudgeon-pin.

Crankcase and Crankshafts

A crankcase of magnesium alloy is fitted. This is in two halves joined along the horizontal centre line of the engine. A detachable nose-piece forms a cover for the main reduction gears.

Two crankshafts machined from solid steel forgings are fitted, one for the two port blocks and one for the two starboard blocks. All journal bearings and crankpins are hollow and of large diameter. Each crankshaft is carried in six plain lead-bronze bearings.

The connecting rod assembly for each crank consists of a forked rod in which the lead-bronze lined steel bearing shell is fixed, and a plain rod which oscillates on the outside of the bearing shell. As viewed from the rear, the first and third plain rods are attached to the pistons in the top cylinders of each bank, the second and fourth to the bottom cylinders. The gudgeon-pin bushes are of phosphor-bronze.

Magnetos

Ignition of the "Rapier VI." engine is by means of two magnetos (B.T.H., or Watford, automatic timing) with sixteen-point distributors all situated at the rear of the engine immediately in front of the supercharger. The timing of the ignition is advanced with r.p.m. by two

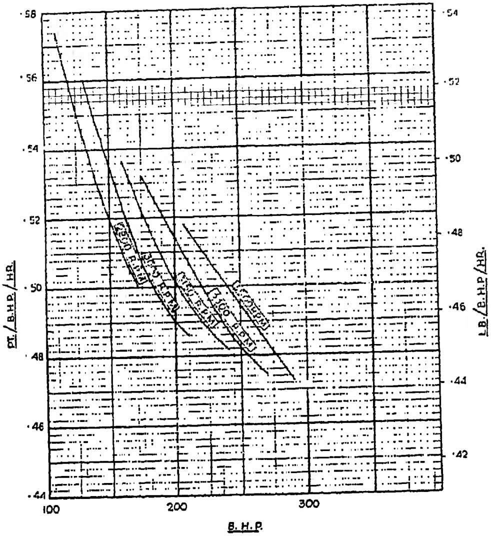


Fig. 6.—NAPIER "RAPIER VI."—ECONOMICAL CRUISING CONSUMPTION.

1½% drop in airscrew r.p.m., 4½% drop in power. Reduction gear ratio ·390 : 1. Method of test: mixture control opened to give the above power drop, then throttle opened to regain the original power.

automatic advance units, one for each magneto. The whole of the H.T. system is screened and bonded to ensure the elimination of interference when wireless is fitted.

Valves and Cowling

One inlet and one exhaust valve per cylinder are provided; each is fitted with two coil springs and operated by rockers. The engine is approximately 780,713 c.c., having the following dimensions :—

Length overall, 4 ft. 8⅝ in. (1,438 mm.)
Width overall, 1 ft. 11⅜ in. (594 mm.)
Height overall, 3 ft. 0 in. (914 mm.)

Performance

At normal rating, 355/370 b.h.p. at 3,650 r.p.m. at 4,750 ft. altitude.

At maximum power rating, 380/395 b.h.p. at 4,000 r.p.m. at 6,000 ft. altitude.

At maximum take-off power, 365 b.h.p. at 3,500 r.p.m. at sea-level.

The net dry weight of the engine including air chutes is 713 lbs. (324 kilos).

The total weight of the accessories is distributed as follows :—

Air compressor (B.T.H. type)	4¾ lbs. (2·2 kilos.)
Air compressor (R.A.E. type, alternative to generator)	9 lbs. (4·1 kilos.)
Airscrew hub (suitable for wooden airscrew)	13½ lbs. (6·1 kilos.)
Exhaust manifold	24 lbs. (10·9 kilos.)
Flame trap and cold air shutter unit .	8¾ lbs. (4·0 kilos.)
Generator (electric)	22½ lbs. (10·2 kilos.)
Gun gear (alternative to vacuum pump) .	2½ lbs. (1·1 kilos.)
Vacuum pump	7 lbs. (3·2 kilos.)

ALVIS "PELIDES" AND "LEONIDES" AERO ENGINES

THE Alvis 1,000 h.p. " Pelides " and 450 h.p. " Leonides " air-cooled radial engines are of advanced design, and incorporate many valuable features.

We give below some of the principal characteristics of the " Pelides " engine :—

Cylinders and Pistons

The barrels, which are bolted to the crankcase, are of nitrided steel and fitted with cast cylinder heads in special alloy. The head is shrunk on to the barrel. Both barrels and cylinder heads are fully finned, and the very efficient cooling so provided permits the use of a high B.M.E.P.

The pistons are the forged type, of robust design. The forged cooling fins beneath the crown provide a stiff support for the gas and scraper rings.

Valves and Rockers

Valves are operated by an independent rocker system completely enclosed in an oil-tight casing. Both inlet and exhaust valves are in high-resistance austenitic steel, the exhaust valve being hollow and sodium cooled. The exhaust valves have stellited seats.

The rockers are mounted in a special device to compensate for any variation of valve clearance caused by the expansion and contraction of the cylinders.

Airscrew Shaft

The airscrew shaft is splined to accepted Air Ministry standards, and has parallel serrations. The airscrew can be driven direct at engine speed, or through reduction gears of the Farman epicyclic type, giving a reduction of 1 : 2 or 13 : 19, thus making the engines suitable for different types of aeroplanes.

Supercharger

Centrifugal type, of high efficiency, having optional gear ratios to enable the engines to be rated to suit the requirements of individual aeroplanes.

Crankshaft and Connecting Rod Assembly

The crankshaft and connecting rod assembly are of robust construction and of well-proved design.

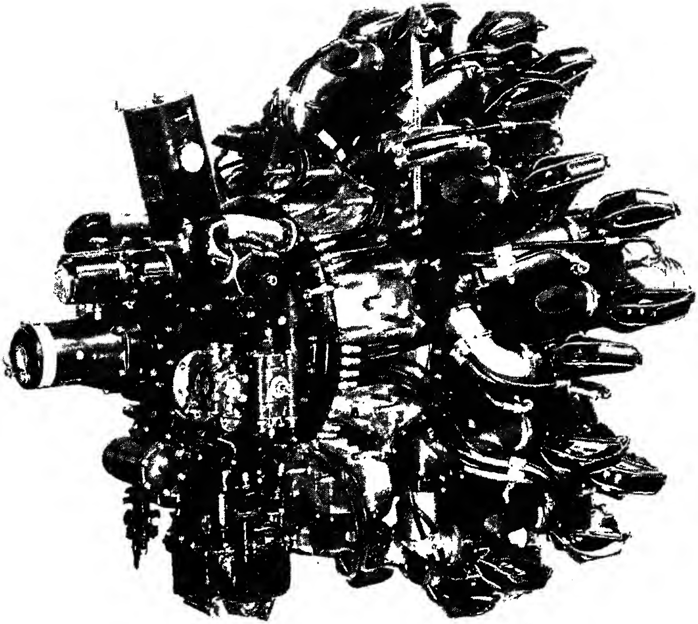


Fig. 1.—THE 1,000 H.P. ALVIS "PELIDES" 14-CYLINDER AIR-COOLED RADIAL AERO ENGINE.

	Pelides.	Pelides Major.
No. of cylinders	14	14
Bore	5·75 in. (146 mm.)	5·75 in. (146 mm.)
Stroke	6·5 in. (165 mm.)	6·5 in. (165 mm.)
Rotation	Left-hand (or right-hand) tractor and pusher.	
Gear ratio	1 : 2, 13 : 19, 1 : 1	1 : 2, 13 : 19, 1 : 1
Diameter	52 in.	52 in.
Nett weight (G.R. 1 : 1)	1,190 lb.	1,190 lb.
Maximum take-off r.p.m.	2,400	2,400
Take-off power at max. take-off r.p.m.	1,075 h.p.	1,000 h.p.
International rated power	1,000/1,050 h.p.	1,000 h.p.
Rated height	5,000 ft. (1,520 m.)	13,000 ft. (3,960 m.)
Maximum climbing r.p.m. / International r.p.m.	2,400	2,400
Max. power for all-out level	1,135	1,110
Fuel	87	87

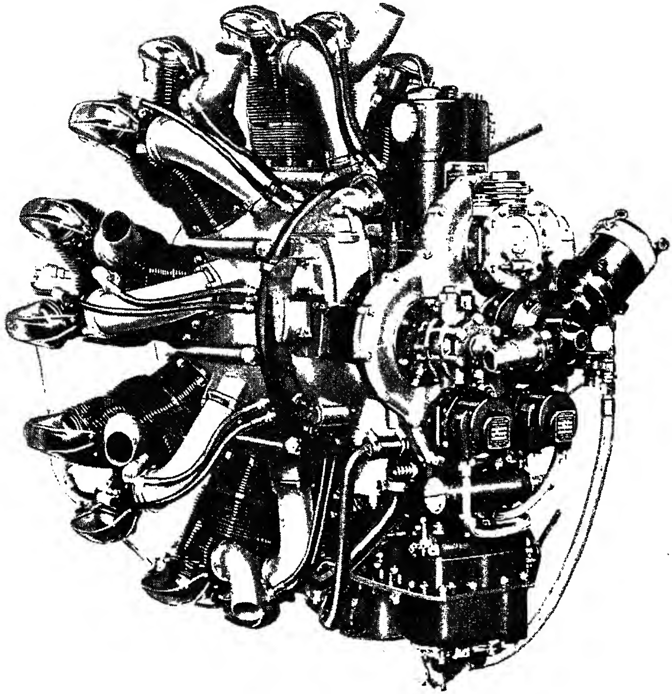


Fig. 2.—THE 450 H.P. ALVIS "LEONIDES" 9-CYLINDER AIR-COOLED RADIAL AERO ENGINE.

Number of cylinders	
Bore	4·80 in. (122 mm.)
Stroke	4·41 in. (112 mm.)
Capacity . .	11·78 litres
Compression ratio .	6·3 to 1
Direction of rotation.	LH tractor

INTERNATIONAL RATED POWER 430 h.p.

At 3,000 r.p.m., 8,500 ft. (2,590 m.) altitude, and + 3 lbs. per sq. in. boost.

MAXIMUM TAKE-OFF POWER 450 h.p.

At 3,000 r.p.m., sea level, and + 5 lbs. per sq. in. boost.

MAXIMUM CONTINUOUS CRUISING POWER . . . . . 410 h.p.

At 3,000 r.p.m., 10,000 ft. (3,048 m.) altitude, and + 2 lbs. per sq. in. boost.

Type of fuel (87 octane) .	D.T.D. 230
Fuel consumption, maximum continuous cruising conditions (Pts./BHP/HR) .	0·59
Type of oil	D.T.D. 109
Oil consumption (pints per hour)	5 to 8

NET DRY WEIGHT (lbs.) 680

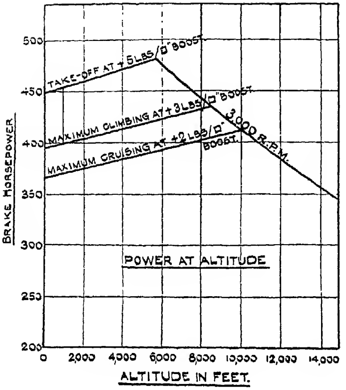


Fig. 3.—ALVIS "LEONIDES" ENGINE—POWER AT ALTITUDE.

Lubrication

The engines are of dry sump design, the principal working parts being lubricated under pressure. The oil supply is effected by one pressure and two scavenging pumps, and the engine is fitted with a special independent and automatic device for oiling the rocker gear under pressure.

The lubricating oil is cleaned at the inlet and outlet of the engine by three suitable filters, one being an easily renewable felt filter which provides exceptionally fine filtration under all conditions.

Accessories

All accessories are built up on the rear cover of the engine, and drives are provided for the following instruments :—

2 compensated cam magnetos of the most modern type.
2 fuel pumps.
3 oil pumps.
1 electric generator.
1 speedometer drive.
1 hand and electric starter.
1 air compressor.
1 vacuum pump.
1 retractable undercarriage hydraulic oil pump.
1 machine-gun drive or spare drive, as required.

The engines can also be fitted with a gas distributor to enable starting either by compressed air or carburised air under pressure.

Ignition

The ignition system, magneto wires and plugs are completely screened to prevent interference with radio apparatus.

Cowlings

The engines are provided with a special attachment allowing for very simple and practical cowlings of the N.A.C.A. type, and supplied with or without cowling gills according to the type of aeroplane. The cowling gills are controlled by simple mechanism, and a special attachment also allows for internal pressure baffles.

Carburation

The engines are fitted with highly efficient carburetters, and the following devices are incorporated in the carburation system : an automatic boost control ; an over-riding control, allowing for a predetermined over-boost for take-off ; an automatic enrichment device ; starter ; and a special anti-freezing carburetter device.

Airscrews

Various types of airscrews can be fitted. The engine is provided with a hydraulic device enabling the de Havilland V.P. or C.P. airscrews to be used, but other airscrews of the fixed or variable type can also be employed.

It is interesting to note the small diameter of the engines, due to their compact design.

MAGNETOS FOR 9-CYLINDER AERO ENGINES

THE following article deals with two magnetos—Rotax "Watford" models S.P. 9–6 and S.P. 9–4—designed to meet the requirements of 9-cylinder aero engines, and giving four sparks per turn of the driving spindle.

"Watford" Magnetos

Both magnetos are made on the principle of the pure inductor. Two cheeks, which are assemblies of laminæ mounted concentrically on a hollow steel spindle, constitute the inductor which runs in a tunnel on ball bearings. The bore of the tunnel presents six poles to the inductor; four of these poles are connected to four permanent bar magnets, the other two forming part of the armature core. The whole of the laminated pole shoes are cast in a casing of aluminium.

The entire magnetic flux system is laminated, and this, together with other points of design, gives powerful and very active alternations through the armature core. The magnetos function perfectly at 8,000 r.p.m. (32,000 sparks per minute).

The S.P. 9–4 magneto is screened against interference to radio equipment, and a centre terminal is provided on the distributor block for booster coil or hand starter magneto.

The usual test voltage, with 6 ft. of braided cable on each lead, is 9,000 volts. Cable fixing unions and sleeves conform to Air Board A.G.S. braided cable standards; the cables are arranged in group formation on the distributor. Advance to retard for the S.P. 9–4 is 15°, but performance on low speeds allows of a maximum range of 30°.

Double contact breaker mechanism of the S.P. 9–6 type provides the means for increase of ignition advance at predetermined positions of the throttle. The mechanism is operated through a lever at the rear of the contact breaker base, interconnected with the engine throttle control. Indication of the relative positions of two contact breakers—X, a fixed position contact breaker, Y, an adjustable position contact breaker and electrical functioning through switch Z—is given in Fig. 1. The lever of the contact breaker Y is angularly positioned to the lever of X, and is operated by the common four-lobe cam. Angular positioning is obtained by movement of the contact breaker round the cam; location and locking is by means of four screws, D, E, F, G.

The primary is connected to Y and to the change-over switch mechanism by a spring H. Interruption of the primary circuit is made by the

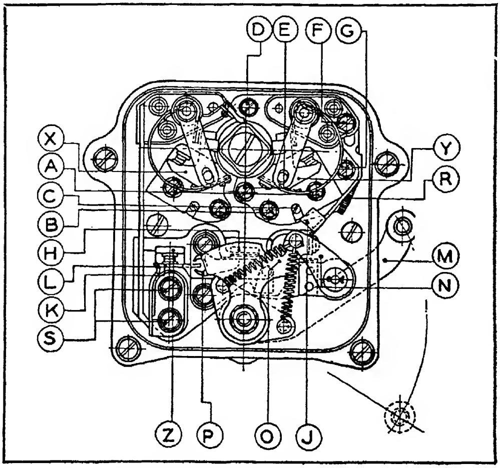


Fig. 1.—CIRCUIT BREAKER FOR "WATFORD" S.P. 9–6 MAGNETO.

adjustable contact breaker when the contact points on contact arms K are open, and by the fixed contact breaker when these points are closed. J is a small platform providing connection to the earth terminal plunger.

A lever M to the rear of the double contact breaker assembly base operates the switch mechanism, a cam O being located on the opposite end of the base spindle. This cam operates the follower N and spring fork P. A snap action for the switch mechanism is achieved by slightly loading the switch contact arm K by a jumper spring L. Adjustment of spring L can be effected by slackening of the screws S.

Contact between O, N and P is maintained by tension springs. When the cam follower falls into the recess on cam O the operating spring fork flexes slightly; when the tension on P reaches sufficient value to overcome the resistance of the jumper spring, the contacts operate quickly.

Contact point adjustment on the fixed and adjustable contact breakers is effected by slackening screws A and B and turning C until a 0·012-in. ($\pm$0·001-in.) gap is obtained; A and B are then tightened.

Installation Notes

Before mounting either of the two magnetos, all thread protectors must be removed.

Spigot mounting is standard B.E.S.A. 90-mm. diameter, attachment being effected by means of three $\frac{5}{16}$-in. bolts. The coupling is attached to the tapered spindle by means of a woodruff key, locknut and washer.

For the S.P. 9–4 the high-tension leads are connected to the distributor by placing them into the unions provided and tightly screwing down the locknut. Connection to a hand magneto or "Watford" booster coil is provided for by a central union.

The distributor screen in the S.P. 9–6 is fitted with a union for the Marconi cable harness. Cables to the cylinders can be led by way of the harness union, and there held in position by piercing screws, if the distributor block is first detached from the magneto and the six screws holding the screen removed. Considerable care should be exercised in ensuring that connections are correct and that the piercing screws are properly fastened down. The screen can then be bolted back to its mounting and the harness union tightly screwed up.

NOTES ON THE ELECTRICAL EQUIPMENT ON "SHORT" EMPIRE FLYING BOATS

THE "Rotax"-model switchboard contains the main switches, and serves, additionally, as a fuse box—fuses for the various circuits being situated under the cover. Connections to the board are made by way of shielded conduits, the unions for which are provided at the top of the boards. Switchboards require little attention other than a routine testing from time to time.

Should the switches become stiff, one drop of oil on the pivots will make for smoother working; should the glass cover to a fuse crack, the fuse should be immediately replaced, for which purpose four spare fuses are carried clipped in the cover. Fuses of a higher value than that indicated should on no account be used.

Switches

Rotax solenoid switches have been developed primarily for the requirements of engine starting and obviate the necessity of running a heavy starter cable to the push button in the cockpit.

A non-functioning switch may be tested by applying 12 volts to the small solenoid terminals and testing between the two main terminals by means of a lamp and battery. If such a test fails to light the lamp, and there is a circuit through the solenoid coil, the cover should be removed and the top plate tried, to ascertain whether or not the plunger is sticking.

Contacts and contact plate should be examined for burns, care being taken to see that the contacts remain absolutely flat after cleaning. The contact plate must remain free on the plunger spindle. A little grease only may be put on the plunger before reassembly, care being taken at the same time that no grease finds its way to the contacts. Parts must fit well and without distortion. In the case of a damaged solenoid, a new pole and coil cup assembly must be procured.

Push buttons are used for closing the solenoid circuit. Should a push button develop a fault it is advisable that it be replaced with another.

The tumbler switch and searchlight switch require no attention, but must be replaced on failure.

Access to the contacts and rachet of the mooring light switch may be had by removing the two screws from the back of the switch. Rack spur

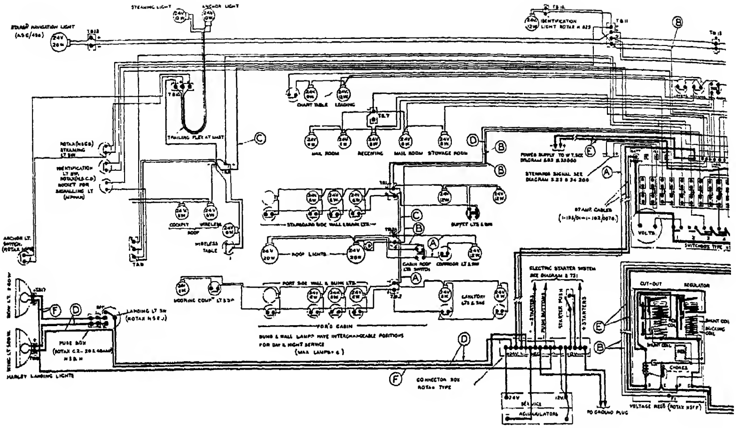


Fig. 1.—ARRANGEMENT OF LIGHTING

and rachet should be lightly greased in the event of the switch becoming stiff. Again, no oil or grease must be allowed to foul the contacts.

Lamps

In dual landing lamps it should be noted that the red lead supplies the main filament, the yellow lead the auxiliary filament, and the black is the return lead. Two filaments should never be alight at the same time. The second filament should be used on occasions when the lamp is required to be lighted for periods upwards of, say, three minutes.

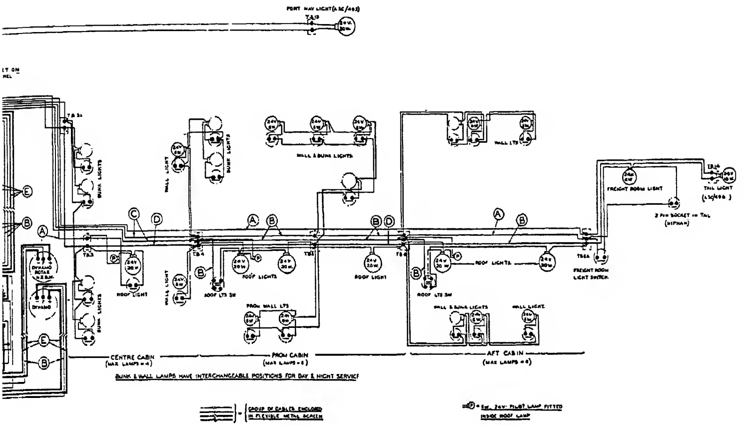
Access to the bulb can be obtained by releasing the three spiral springs at the back of the case at the lamp rim. The reflector or lens must not be touched with the fingers. Removal of the bulb is secured by giving one half-turn to the left and pulling gently ; a new bulb is fitted by placing in the socket, pushing home and giving one half-turn to the right. Locking is automatic.

When replacing a double filament bulb, the auxiliary filament of the dual lamp must be parallel to the base of the lens, and must lie in the lensed half of the reflector. The 24-volt bulbs have an estimated life of 100 hours ; replacement should therefore take place every fifty hours.

Battery systems must be kept in perfect condition against the possibility of filament overload and burning out.

Navigation and Cabin Lamps

If a light should fail—and the bulb on testing prove to be in working order—the fuse for the particular circuit in the switchboard should be



IN "SHORT" EMPIRE FLYING BOAT.

examined, and if blown, replaced. Frayed or damaged cable should be replaced at once. Connections to the lamp should be inspected to see that they are in no way defective.

To gain access to the bulbs in the two side navigation lamps, the knurled ring must first be unscrewed, and the mask, packing ring and glass can then be pulled off. Bulbs are released with the normal bayonet action. The tail lamp can be opened in a similar manner.

To remove the glass from the landing signal lamp the nickel-plated ring must be turned to the right, thus releasing the spring and allowing the glass to be removed.

The glass can readily be removed from mooring and steering lights by unscrewing the knurled ring to the right. As with the two side lamps, care must be taken to see that the two packing rings are replaced.

All lamps must be kept clean. A light dusting with a chamois leather is all that is required for the polishing of the rims and reflectors of the roof lamps.

Booster Coil

The N.I.K.A. booster coil provides a ready means of obtaining a "hot" spark for starting. The coil is connected in parallel across the starter by means of the two cable clamps under the unsealed cover, *viâ* the two small unions, and is thus brought into action immediately the starter button is pressed.

No attempt should be made to re-set the coils. Special apparatus is required for correct setting, and for this reason the adjusting screw

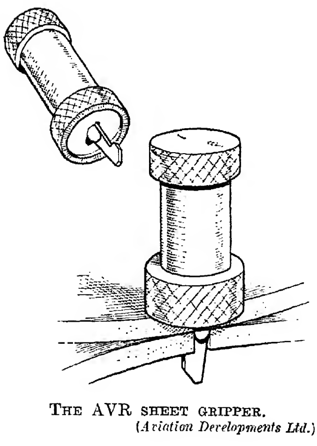
cover is sealed. Should it, however, be imperative that the coil be re-set, access to the adjusting screw can be gained by breaking the seal, slacking off the locknut and swivelling the cover to one side. If an ammeter be connected in series with the coil and a current of 12 volts applied to the primary winding, the points can be adjusted so that current consumption of the coil is 1·2 to 1·4 amperes. At this setting there should be regular sparking across a 9-kilovolt standard gap when distributed to this *viâ* a magneto rotating at 60 r.p.m.

Points can be cleaned by removing the base plate. Care must be exercised that the tremblers are left unbent. Fine carborundum cloth and benzine should be used for cleaning, and both coil and contact must be left dust-free.

Temperature-Indicating Equipment

The Rotax-Weston engine temperature-testing installation consists of a copper-constantan thimble thermometer working in conjunction with an indicator. Connection from the engine to the instrument is made with compensating leads of the same materials as the couple and having the same resistance. The cylinder connection and the asbestos whipping should be inspected from time to time.

THE AVR SHEET GRIPPER



THE AVR SHEET GRIPPER.
(*Aviation Developments Ltd.*)

A particularly useful accompaniment to blind and other forms of riveting in Aircraft Construction is to be found in the AVR sheet gripper.

This little tool is the invention of that well-known pioneer, Sir Alliott Verdon-Roe, and is intended for use in place of bolts and nuts or screws.

It consists of a stepped claw which is inserted through the rivet holes, and then by simply bearing down on the tool and screwing up, the sheets are drawn together. The base of the tool is formed with a projecting spigot of the same diameter as the rivet hole, and as the several sheets are drawn together this spigot engages and accurately locates them.

The operation is clearly shown in the accompanying illustration.

THE NAPIER-HALFORD "DAGGER III" AIR-COOLED AERO ENGINE

THE normal rating of this engine is 700/725 b.h.p. at 3,500 crankshaft r.p.m. at 3,500 ft. Its power at maximum speed is 780/805 b.h.p. at 4,000 crankshaft r.p.m. at 5,000 ft.

Weight of the engine, on rated power, is 1·80 lbs. (·82 kilo) per b.h.p.; on maximum power, 1·62 lbs. (·74 kilo) per b.h.p.

The net dry weight of this tractor type engine without airscrew hub, generator, air compressor or gun gear is 1,305 lbs. (592 kilos), this weight being inclusive of air chutes, baffles and engine feet. Of the accessories, the airscrew hub is 26 lbs. (11·8 kilos), the generator 22½ lbs. (10·2 kilos), the air compressor 4¾ lbs. (2·2 kilos) and the gun gear 2½ lbs. (1·1 kilos).

Airscrew and Crankshafts

The reduction ratio of the airscrew shaft is 1 : 2·69 of crankshaft, giving 1,302 r.p.m. at normal speed and 1,488 r.p.m. at maximum speed. Viewed from the airscrew end, the shaft rotates clockwise—that is, it is a L.H. tractor.

Two bearings carry the shaft, and a ball bearing to take the journal and thrust loads of the airscrew is fitted at the airscrew end of the shaft. Reduction between the airscrew shaft and the crankshafts is effected by case-hardened spur gears.

Two crankshafts machined from solid steel forgings are fitted, one for the two port blocks and one for the two starboard blocks, and each crankshaft is carried in eight plain lead-bronze bearings. All journal bearings and crankpins are hollow and of large diameter.

The connecting rod assembly for each crankshaft consists of a forked rod in which the lead-bronze lined steel bearing shell is fixed, together with a plain rod which oscillates on the outside of the bearing shell. Groups of three constitute the arrangement of the assemblies; the front three starboard and the rear three port plain rods are attached to pistons in the top cylinders, and in the other cylinders the positions of the forked and plain rods are reversed. Gudgeon-pin bushes are of phosphor-bronze.

The crankcase is of aluminium alloy, and is in two halves. Separate engine feet are provided for attachment to the aeroplane, and a detachable nosepiece, forming a cover for the main reduction gears, houses the drives for the magnetos and the distributors.

A Rotax "Eclipse" type inertia starter is fitted to operate by way of bevels upon the rear end of the port crankshaft. An electrically energised type of inertia starter may be substituted for the hand-energised type if required.

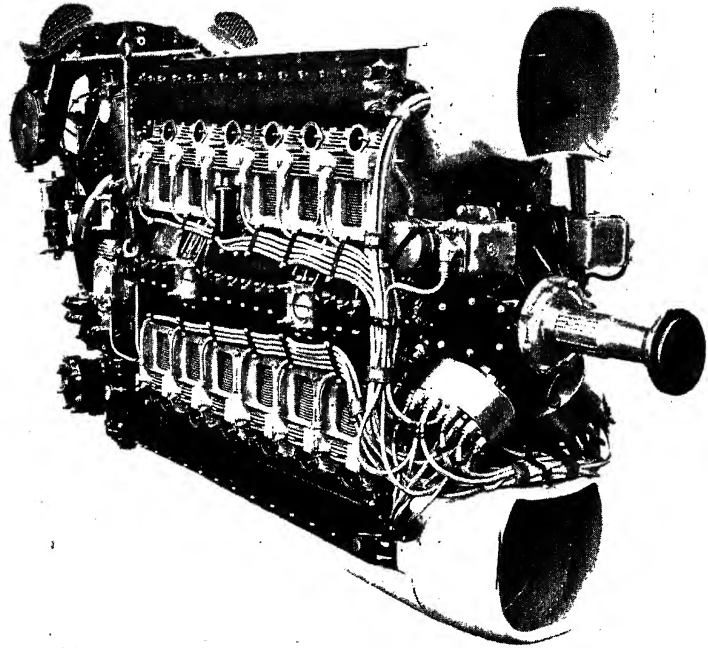


Fig. 1.—THE NAPIER-HALFORD " DAGGER III " AIR-COOLED AERO ENGINE.

Cylinders

The twenty-four cylinders of the " Dagger " Series III engine are in " H " formation, arranged in four blocks of six each, two vertical and two inverted.

ession ratio are, $3\frac{13}{16}$ in. (97 mm.), $3\frac{3}{4}$ in. (95 mm.) and 7·75 : 1 respectively. Cylinders are steel forgings machined all over, and the cylinder heads (of aluminium alloy) contain inlet and exhaust passages, valves and valve actuating mechanism. One inlet and one exhaust valve per cylinder, each fitted with two coil springs and operated by hydraulic rockers, are provided, and the whole of this valve mechanism is completely enclosed.

Oil Pumps, Consumption and Lubrication

One pressure pump and two scavenge pumps are fitted, the pressure pump taking the oil from the supply tank and delivering it under

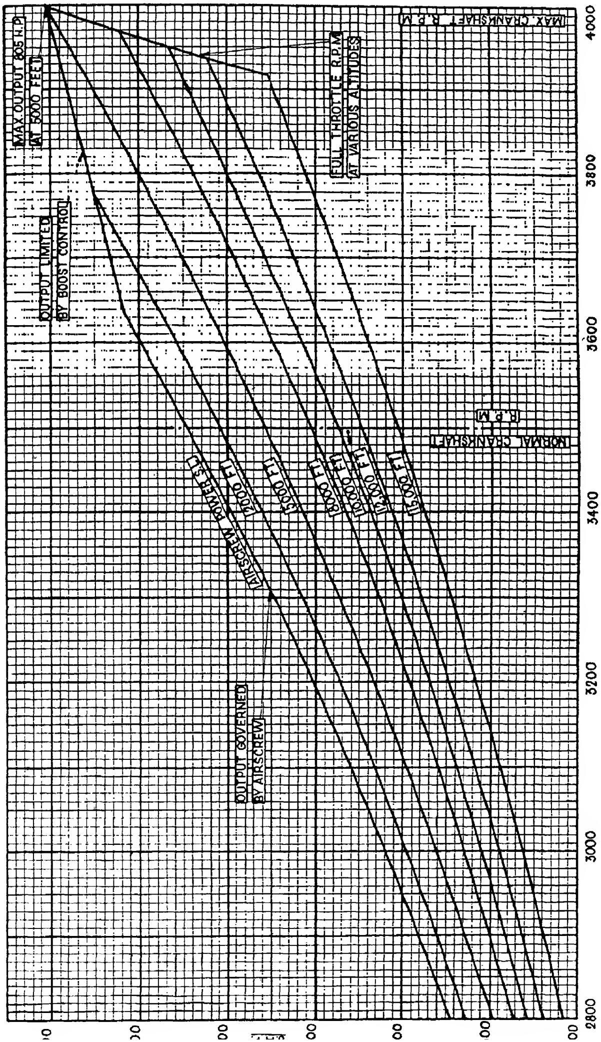


Fig. 2.—NAPIER-HALFORD "DAGGER III"—POWERS AVAILABLE IN LEVEL FLIGHT.

Airscrew 205 H.P. at 5,000 feet at 4,000 r.p.m. Reduction gear ratio ·372. Rated altitude 3,500 ft. Rated boost 16·95 lbs./□ A.B.S. Fuel D.T.D. 230.

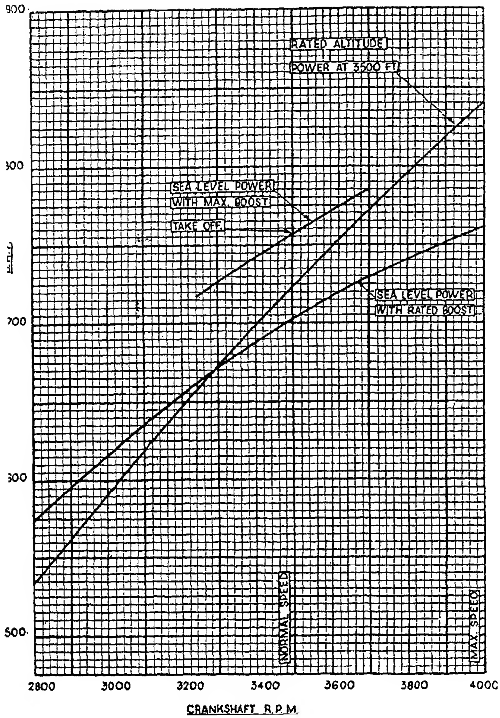


Fig. 3.—NAPIER-HALFORD "DAGGER III"—POWER CURVES.

Normal speed 3,500 r.p.m. Rated boost $2\frac{1}{4}$ lbs./□"g., max. speed 8,000 r.p.m., max. boost Reduction gear ratio ·372 : 1.

pressure to the working parts of the engine. The suction pumps scavenge the oil sump and return the oil to the supply tank. Two "Tecalemit" filter elements are fitted in tandem between the pressure pump and the engine.

Two filters for the scavenged oil are embodied in the oil sump of the engine, and these filter the oil before it enters the suction pumps. The sump, containing the oil pumps, oil relief valves and filters for the scavenge pumps, is attached to the underside of the timing gear case.

Oil to be used is to A.M. Specification D.T.D. 109, and the consumption, on Air Ministry Acceptance Test, must lie between 6 pints (3·41 litres) and 13 pints (7·38 litres) per hour, subject to a tolerance of + 10 per cent. With lubricating oil having a specific gravity of ·91, this is equivalent to a maximum consumption of ·026 lb. (11·7 grams) per b.h.p. per hour, when the engine is developing 630 b.h.p. The oil consumption on the Air Ministry Type Test averaged 6·52 pints (3·7 litres) per hour during 90 hours' running at 628 b.h.p. and 3,500 r.p.m. This is equivalent to ·0118 lb. (5·4 grams) per b.h.p. per hour.

Lubrication is by high pressure to the crankshaft journals, big ends and gudgeon pins. The reduction gears are lubricated by oil projected on the teeth from two jets fed by the high pressure system. Oil from this system is passed through a reducing valve to form a low pressure system,

which lubricates the remainder of the engine. The escaping oil from the various bearings, etc., is drained into the oil sump and returned to the supply tank by scavenge pumps. An adjustable pressure relief valve is incorporated for the high pressure oil supply.

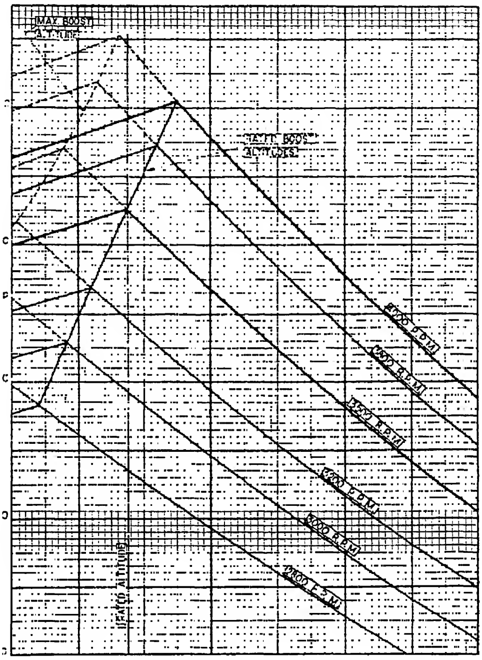


Fig. 4.—NAPIER-HALFORD "DAGGER III"—PERFORMANCE AT ALTITUDE.

Normal speed 3,500 r.p.m. Rated boost 16·95 lbs./□" ABS., max. speed 4,000 r.p.m., max. boost 18·2 lbs./□" ABS. Take-off output 755 b.h.p. at 3,500 r.p.m.

Fuel Pump and Consumption

The fuel pump is of the gear-wheel type and is fitted on the starboard side of the engine. A cross-shaft situated at the rear of the engine provides driving power for the pump, and a packing ring is provided on the shaft to prevent leakage of fuel. Incorporated in the pump is a relief valve, which is controlled by a light phosphor-bronze spring adjusted so as to give adequate supply of fuel under all conditions.

Fuel conforms to the Air Ministry Specification D.T.D. 230, and consumption at economical mixture strength (drop $1\frac{1}{2}$ per cent., r.p.m.) is ·461 pint (·262 litre) per b.h.p. per hour at 580 b.h.p. at 3,500 r.p.m. This is equivalent to ·430 lb. (195 grams) per b.h.p. per hour with fuel of a specific gravity of ·748.

Magnetos and Pistons

Ignition is by two magnetos with separate twenty-four point distributors all driven from the airscrew shaft. The timing of the ignition is advanced with r.p.m. by two automatic advance units, one for each

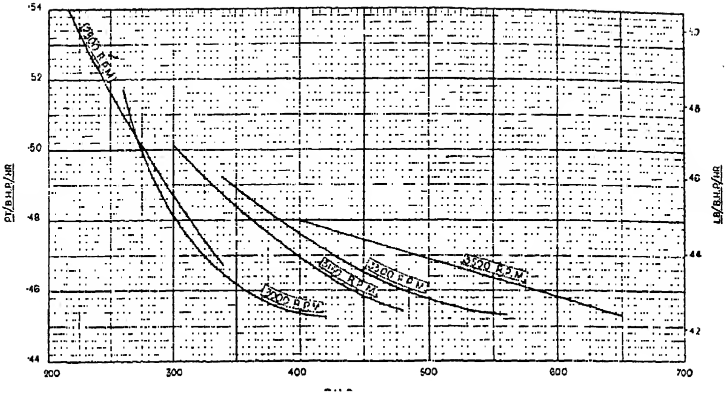


Fig. 5.—NAPIER-HALFORD "DAGGER III"—ECONOMIC CRUISING CONSUMPTION.
$1\frac{1}{2}$% drop in airscrew r.p.m. $4\frac{1}{2}$% drop in power. Method of test: mixture control opened to give the above power drop, then throttle opened to regain original power.

magneto. The whole of the high tension system is bonded and earthed to secure the elimination of interference when wireless is fitted.

Pistons are of forged aluminium alloy, and each is fitted with two gas rings, one scraper ring and a hollow gudgeon pin.

A supercharger of the centrifugal fan type is fitted at the rear of the engine. The impeller is driven from an extension of the airscrew shaft through layshafts by means of special spur gears. A differential gear is fitted to balance the drive, with a friction disc clutch for protection against sudden changes of speed. An automatic boost control unit is fitted.

A special Napier Claudel-Hobson downdraught carburetter is fitted above the supercharger, and the body, which is of aluminium alloy, is oil-jacketed around the intake volute and the choke.

Two drives are provided at the rear of the engine: one for a B.T.H. air compressor, and another for a standard R.A.E. spigot-mounted 500-watt generator.

In addition to the components already described, the engine is supplied with air chutes and baffle plates suitably arranged for a "Tractor" aircraft.

The c.c. of the Napier-Halford "Dagger" Series III engine is approximately 1,359,944, of the following linear measurements :—

Length overall, 6 ft. 8 in., approximately (2,032 mm.).

Width overall, 1 ft. 11 in., approximately (584 mm.).

Height overall, 3 ft. $9\frac{1}{8}$ in., approximately (1,146 mm.).

NOTES ON THE PRODUCTION OF THE PERSEUS SLEEVE VALVE ENGINE

By A. C. Clinton, A.F.R.Ae.S.

THE Perseus sleeve valve engine is fitted in military and civil aircraft, and is designed for medium or full supercharge according to the duty required. In general construction it is similar to the poppet valve engines of the Mercury and Pegasus types; the fundamental difference is the valve system involving a special cylinder assembly and a modified front half crankcase. These parts will be referred to later.

When compared with the poppet valve the sleeve valve engine has a number of technical and constructional advantages and the latter make production a simpler matter which in turn means less time.

All the major parts are relatively simple and can be produced accurately and quickly with automatic or semi-automatic machine tools. It will be noted that the valve mechanism is fundamentally simple and is suited particularly to high-speed production, as not only is the total number of components less than in the poppet valve type, but there are no small highly stressed parts. Further, as the engine type is developed for larger sizes there would be no excessive increase in the cost of production.

Nearly all the machining of the parts comprising the cylinder assembly can be dealt with by turning, grinding, boring and drilling, important considerations which reduce the number of special purpose machines to a minimum.

Sleeve Valve

The sleeve valve is made from an alloy steel specially chosen so that its coefficient of expansion is not greatly different from that of the light alloy barrel, as it is essential that correct working clearances are maintained in order that the system shall be gas-tight and at the same time be efficiently lubricated.

In the poppet valve engine the bore of the cylinder always shows greatest wear opposite the top piston ring, and the wear decreases along the length of the piston travel, but such local wear does not occur in the sleeve valve type. The combined rotary and reciprocating motion of the sleeve is good for spreading the oil evenly and it has been found from experience that the wear is almost negligible.

For the purpose of manufacture the sleeve may be considered as a tube, and it can be made by extrusion, or spinning rather similar to the

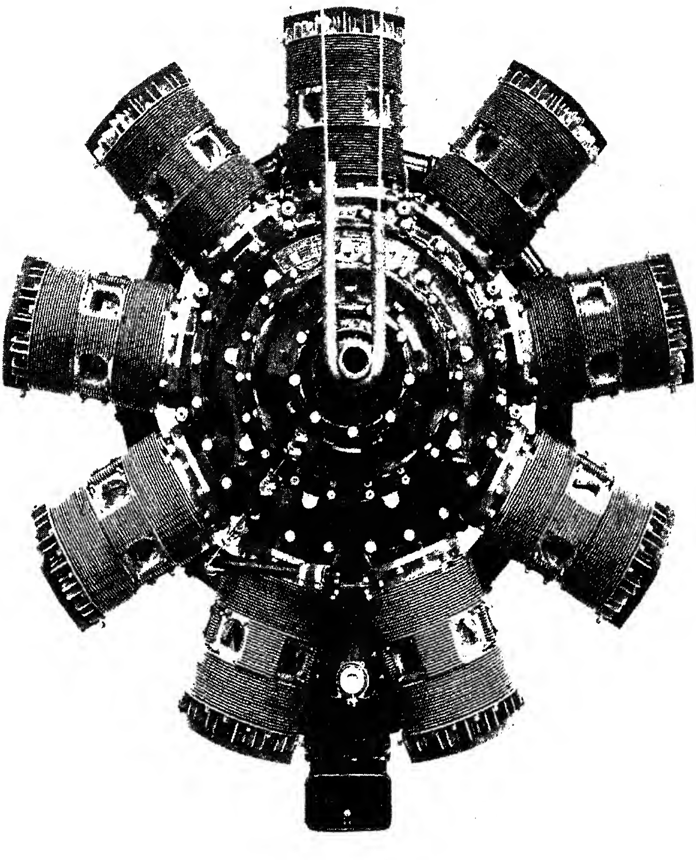


Fig. 1.—THE PERSEUS ENGINE (FRONT).

THIS FINE EXAMPLE OF BRITISH AERO ENGINEERING IS A SLEEVE VALVE ENGINE DESIGNED AND MANUFACTURED BY THE BRISTOL AEROPLANE CO. LTD.

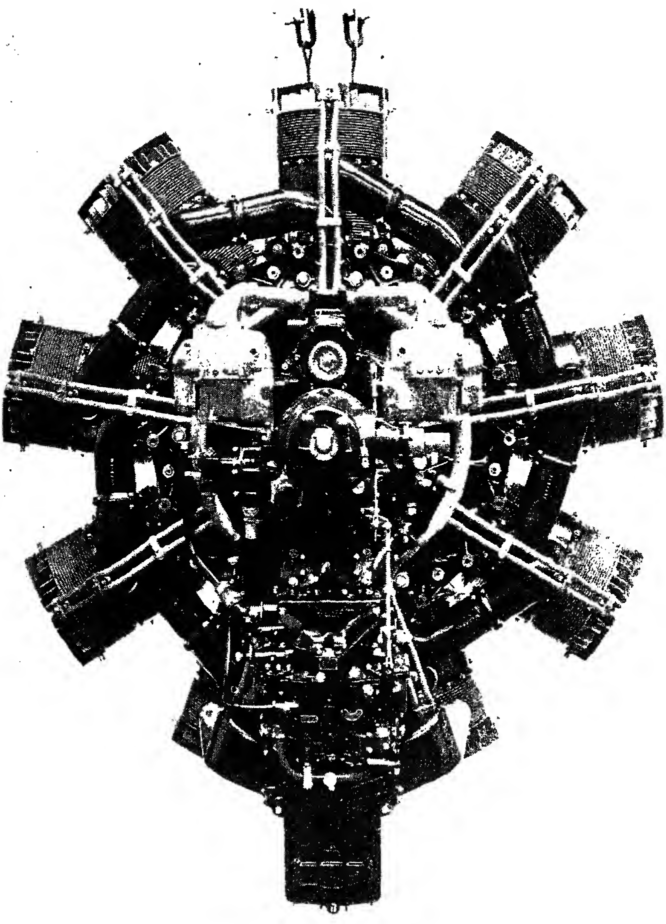


Fig. 2.—THE PERSEUS ENGINE (REAR).

WHEN COMPARED WITH THE POPPET VALVE, THE SLEEVE VALVE ENGINE HAS A NUMBER OF TECHNICAL AND CONSTRUCTIONAL ADVANTAGES, AND THE LATTER MAKE PRODUCTION A SIMPLER MATTER, WHICH IN TURN MEANS LESS TIME. ALL THE MAJOR PARTS ARE RELATIVELY SIMPLE AND CAN BE PRODUCED ACCURATELY AND QUICKLY WITH AUTOMATIC OR SEMI-AUTOMATIC MACHINE TOOLS.

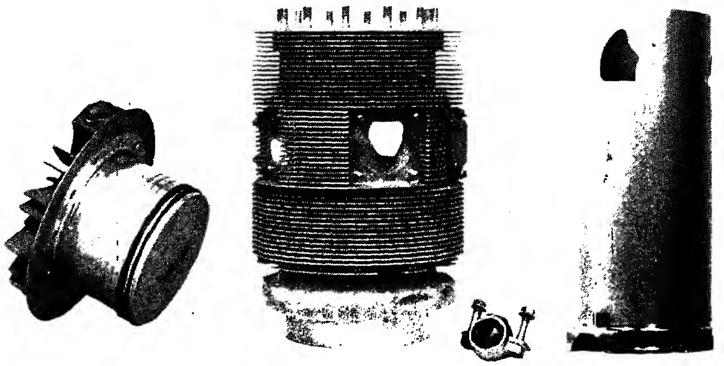


Fig. 3.—SHOWING SLEEVE, BARREL AND JUNKHEAD.

centrifugal casting of iron pipes; this method gives fairly rapid cooling and any impurities tend to be centrifuged to the outer surface. Fig. 3 shows the sleeve, barrel and junkhead.

The rotary and reciprocating motion of the sleeve is imparted by the sleeve drive cranks operating through the ball and socket unit attached to the skirt of the sleeve, and it will be realised that there is a considerable force to be handled at this point. Further, the sleeve thickness is comparatively thin and must withstand the explosion pressure without bulging into the ports of the barrel, therefore the sleeve, besides having the necessary strength properties, must be made with careful attention to grain flow, especially at the skirt carrying the ball and socket joint.

The machining of the sleeve valve is similar to that of a cylinder liner; it is turned and bored, the ports are cut and both surfaces are carefully ground. Fig. 4 shows the machining of the ports in the sleeves and barrels.

The sleeve is subjected to many inspections during its course of manufacture, including X-ray; the internal and external dimensions of the sleeve are finally checked on a " Solex " indicator.

The boring and drilling of the sleeves and crankcases is shown in Fig. 5.

Crankcase

The crankcase consisting of front and rear half is made from an aluminium forging. The front half which carries the train of gears and sleeve driving cranks has the requisite number of radially disposed holes, and these are drilled in a multi-spindle machine; another point of difference

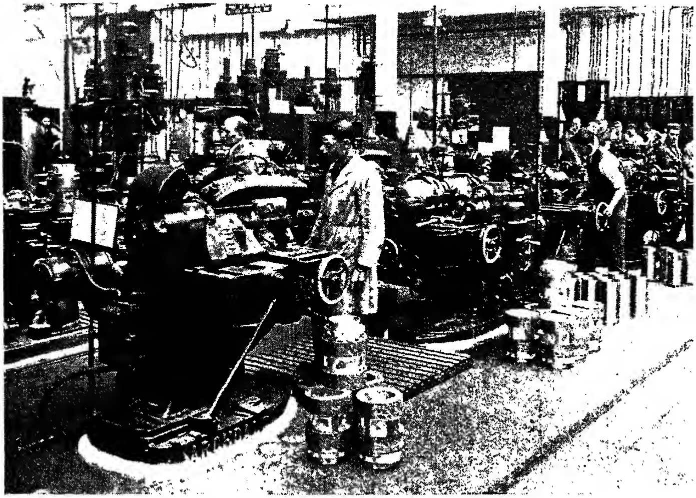


Fig. 4.—CUTTING THE PORTS IN SLEEVES AND BARRELS.

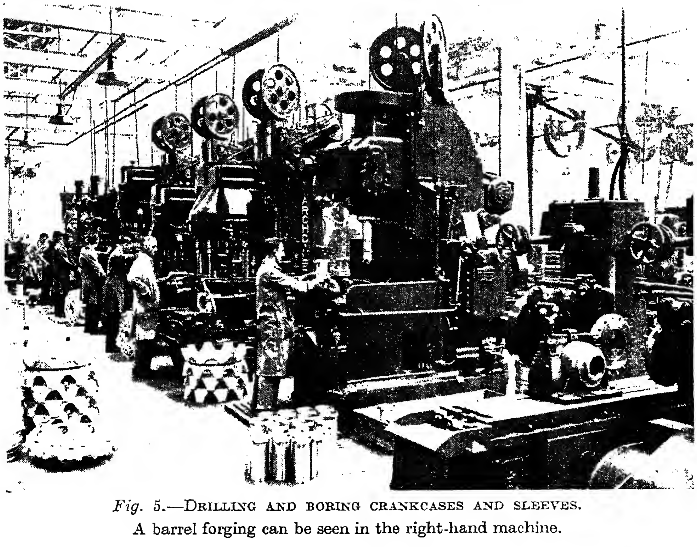


Fig. 5.—DRILLING AND BORING CRANKCASES AND SLEEVES.
A barrel forging can be seen in the right-hand machine.

compared with poppet valve is that the cylinder barrel aperture is shaped to provide suitable clearance for the ball and socket joint. The rear half crankcase is generally similar to the poppet valve type.

Junkhead or Cylinder Head

The junkhead shown in Fig. 3 is made from an aluminium die casting, and when compared with the cylinder head of the poppet valve engine is seen to be much simpler in construction and requiring comparatively little machining.

The fins are cleaned up to remove any roughness remaining after casting, and all radii are blended with care, since it is important that there is the minimum of skin friction to affect the flow of cooling air in and out of the head.

Holes are drilled for the studs and sparking plugs, and the part which fits inside the barrel to seal the sleeve is turned and the grooves cut for the piston rings.

Cylinder Barrels

The barrels are made from aluminium forgings and have close pitched fins machined all over except where the inlet and exhaust ports are situated. At these parts the barrel is turned down to the fin root diameter. The barrel is bored, and the ports are cut on an automatic machine. Other operations deal with drilling, (*a*) the lower flange for the holding down studs, (*b*) the holes at the top of the barrel to take the studs for securing the junkhead, and (*c*) the stud holes at the ports for holding the induction manifold and the exhaust outlet pipe.

The finishing of the ports by scruffing and polishing is important so that the best flow of gas is ensured according to the movement of the sleeve.

Sleeve Drive Cranks

These right-angle cranks are machined from an alloy steel forging carefully made to ensure correct grain flow. The cranks are turned and ground in the usual way, the front pin of the crank is splined to engage with the appropriate driving pinion, and the rear pin is lapped and fits into the bronze ball of the socket joint at the bottom of the sleeve.

Piston

This is a light alloy drop forging and is similar to the Pegasus design. It has four piston ring grooves and is diamond turned in the usual way.

Fitting and Sub-assembly. Crankshaft and Connecting Rods

With the exception of the cylinder assembly and the train of gears in the front half crankcase for driving the sleeve drive cranks, the unit assembly of the Perseus is generally similar to the poppet valve types.

The front and rear halves of the built-up crankshaft are assembled separately, with the main bearing inner race, crankshaft oil sleeve, etc. The crankshaft tailshaft is fitted to the rear half crankshaft.

The connecting rod assembly can then be assembled on to the crank-pin, care being taken to ensure absolute cleanliness and plenty of oil. The rear half crankshaft is then fitted to the front half by expanding the maneton bore, care being taken to see that the crankpin and maneton bore are quite clean and free from oil or grease. When completely assembled the crankshaft and connecting rod assembly is subjected to an oil pressure test to ensure that the oil plugs are tight, and that oil exudes where necessary for lubricating the floating bush, articulated rod pins, etc.

Reduction Gear Unit

The reduction gear unit consisting of the airscrew shaft, bevel pinions, bevel gears and bearings and front thrust bearings is then assembled ready for building into the engine.

Supercharger Unit

This unit includes the assembly of the spring drive gear, intermediate gear and pinions which is built in to the blower casing, the whole unit being completed by the fitting of the impellor. The volute casing and cover is then assembled to the blower casing.

Crankcase

The two half crankcases are studded, and fitted with bearing housings, the front half being fitted with the bearings carrying the train of gears and the sleeve drive crankpins. The gears and cranks are finally fitted and timed, so that the cranks are in the correct position for receiving the ball and socket joint at the lower end of the sleeves.

Rear Cover

The rear cover with its drives and accessories is then built up and tested. The engine serving accessories fitted include tachometer drive, fuel pump, oil pump, electrical starter with auxiliary hand crank, independent dual contact breaker magnetos with fully screened H.T. equipment and governor for constant speed airscrew control.

Accessory Drive Gearbox

In the poppet valve installations it has been usual to carry on the engine rear cover all the accessories for serving both the engine and the aeroplane, but in the sleeve valve installation the layout has been changed with great improvement in general efficiency.

The rear cover carries the engine accessories as already mentioned, and the aircraft serving accessories are mounted on an auxiliary gearbox

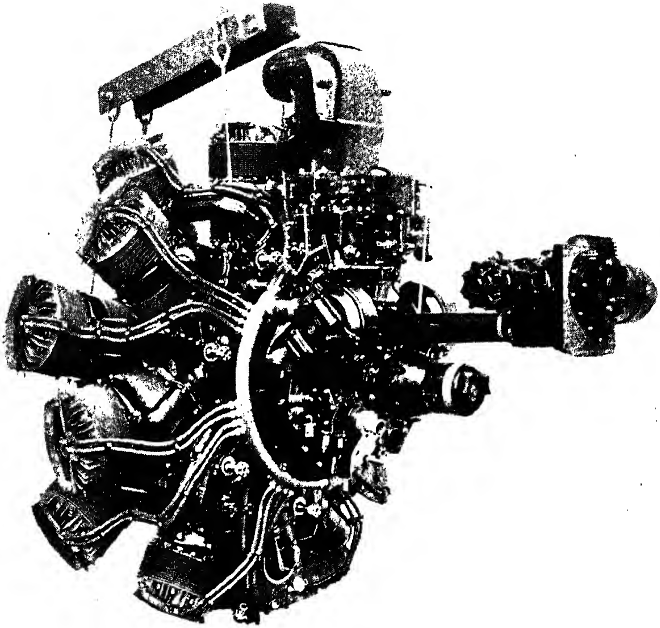


Fig. 6.—HERCULES ENGINE WITH AUXILIARY GEARBOX AND DRIVE.

situated on the bulkhead of the airframe and driven from the engine by a flexibly jointed shaft.

There are two types of gearboxes for mounting either four or six accessories. The boxes are fitted with different internal drives according to the type of accessory, its speed and direction of rotation. The accessories include electric generator, Dowty undercarriage pump, Pesco vacuum pump, Romec vacuum pump, Northern oil pump, R.A.E. air compressor ; if all the accessories are not fitted the free drive faces of the gearbox are fitted with blanking covers. Fig. 6 shows a Hercules two-row sleeve valve engine with auxiliary gearbox and drive.

Testing Gearboxes

It is usual to test the gearboxes as a self-contained unit and not with engine, and for this purpose a special electrical test plant is used which subjects the various drives in the gearbox to loads corresponding to those experienced in actual practice.

The test begins with a quarter of an hour at a slow speed for running-in,

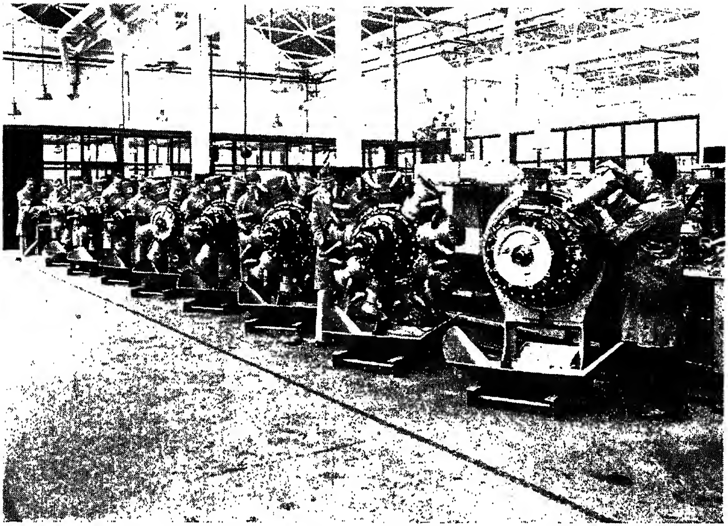


Fig. 7.—Erecting the Perseus engine.

and during the next quarter of an hour the driving shaft speed is progressively increased to the equivalent of the normal engine speed. These conditions are then maintained for one and a quarter hours, after which the box is driven at maximum speed for a further quarter of an hour. This portion of the test concludes with five accelerations from slow running-up to maximum speed each within three seconds.

The gearbox is then completely dismantled and carefully inspected in detail, and, if satisfactory, a final acceptance test is run off; this comprises a progressive run-up for ten minutes to normal speed, followed by quarter of an hour at normal speed and five minutes at maximum speed.

Erection of Engine. Crankcase

The rear half crankcase is fitted to the engine building stand, then the crankshaft and connecting rod assembly is suspended in position, the bearing rollers are assembled and then fitted to the rear half crankcase. The front half crankcase is assembled on to the crankcase bolts with the cylinder half apertures correctly aligned with those of the rear half crankcase, care being taken that the front and rear oil sump joint faces are in line, at the same time seeing that any necessary adjustment is made to the alignment of the assembly rollers on the inner race in the front half crankcase. The crankcase bolts are then tightened.

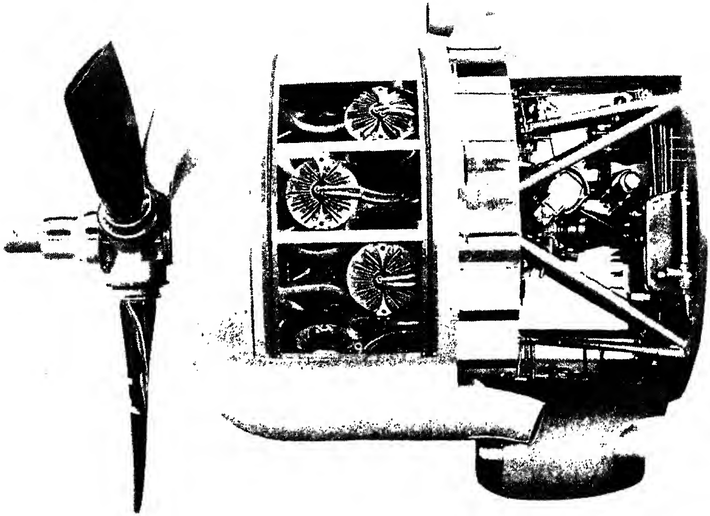


Fig. 8.—HERCULES POWER-UNIT INSTALLATION.
Showing accessory gearbox mounted on the bulkhead.

Pistons, Sleeves and Cylinders

Number six cylinder should be assembled first.

1. Assemble the piston to the connecting rod and press in the gudgeon pin. Fit the steel rings and circlips.

2. Turn the crankshaft to bring both the sleeve driving crank and piston to T.D.C. position.

3. Evenly space the gas and scraper ring gaps.

4. All working surfaces must be smeared with clean mineral oil when assembling.

5. Assemble the sleeve ball and housing on the crank end. Fit the sleeve guides to the ball housing studs and assemble the sleeve using the piston ring clip to facilitate entry of the piston rings (Fig. 7). Thread on the ball housing nuts and screw home. Remove the guides and tighten the nuts using the special spanner provided. Finally lift the locking plate with the tool provided and rotate to engage with the serrated flange of each nut.

6. Immediately before fitting the cylinder, fit the rubber sealing ring previously dipped in engine oil. Ensure that the ring is not twisted when finally positioned on the cylinder spigot. Slide the cylinder over the sleeve noting that the induction pipe sleeves, rubber ring and ring holder

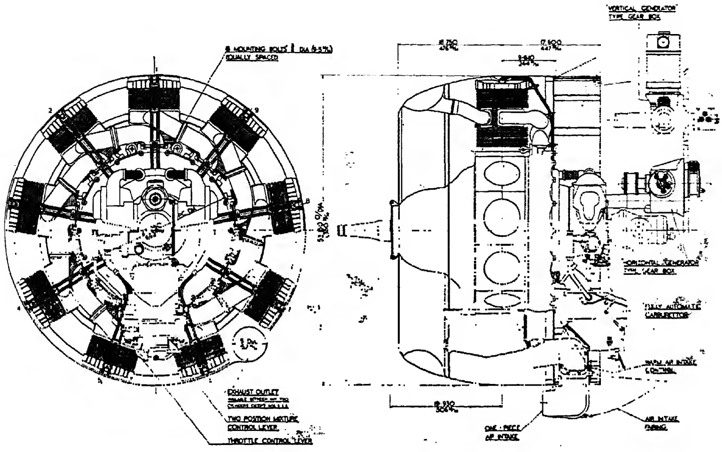


Fig. 9.—INSTALLATION DIAGRAM FOR PERSEUS ENGINE.

are in position on the induction pipe; fit the plain and spring washers and tighten the cylinder securing nuts.

7. Assemble the cylinder head using the special cylinder head ring band to facilitate entry of the cylinder head rings into the sleeve bore. Fit the plain spring washers and tighten the securing nuts.

8. Secure the induction pipe ring holder with the bolts and spring washered nuts. Fit the H.T. wires and clips.

9. The sump is now fitted.

10. Assemble the inter-cylinder baffles noting that the distance pieces are in position on the cylinder head studs prior to tightening the baffle bracket securing nuts. Finally connect the exhaust pipes.

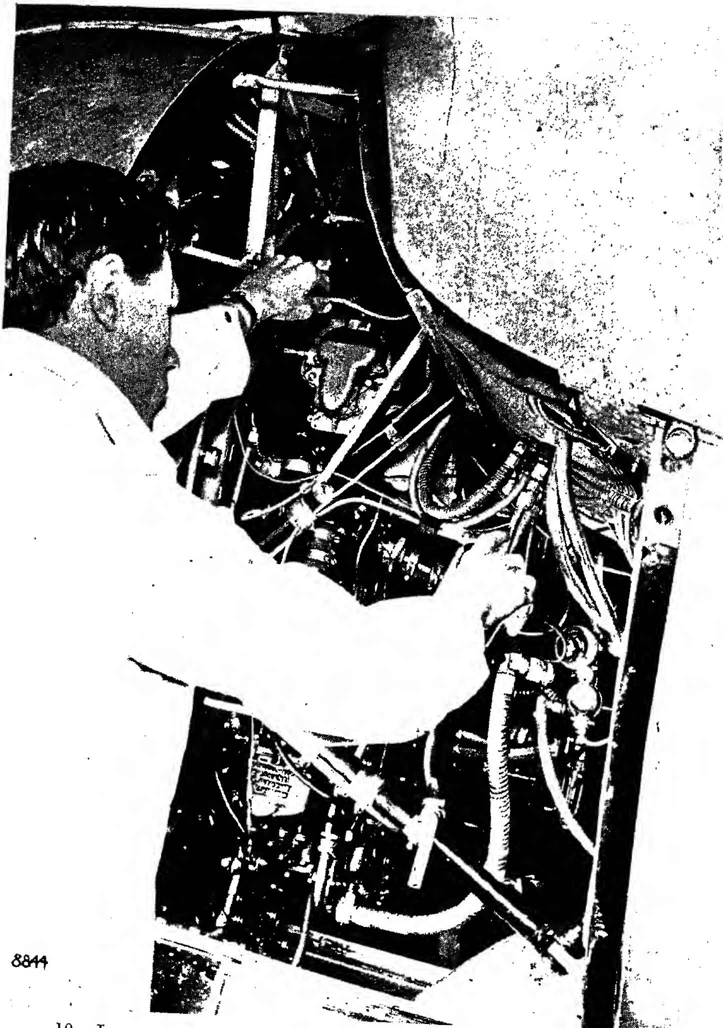
The other sub-assemblies, similar to the poppet valve, including front cover, reduction gear unit, supercharger unit, carburetter, rear cover unit and ignition system, are built on to the crankcase following the usual practice, and the necessary check tests are made.

Engine Test

After the engine has passed inspection following erection it is passed to the running-in shop where it is run for five hours on spindle oil, which is supplied very copiously in order that any stray dirt may be washed away.

An electric motor rotates the engine at about 500 r.p.m., and in place of sparking plugs gauze-covered blanks are fitted.

After being run-in the engine is transferred to the dynamometer test stand, and the necessary pipe lines and controls are fitted.



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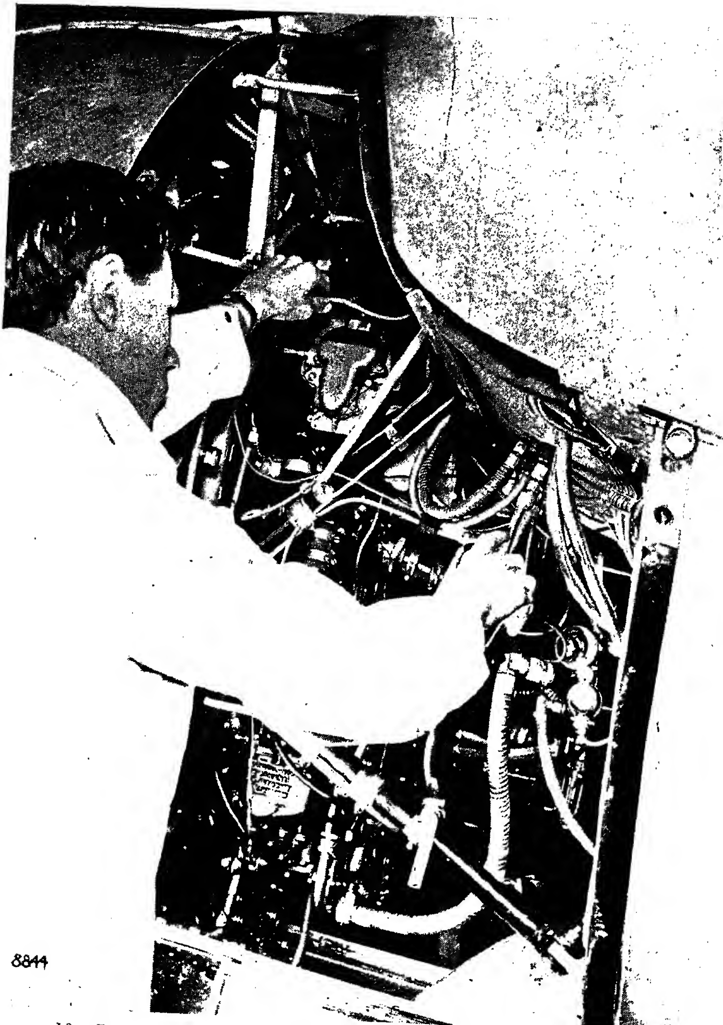
10.—INSTALLATION OF PERSEUS ENGINE IN DE HAVILLAND "FLAMINGO."



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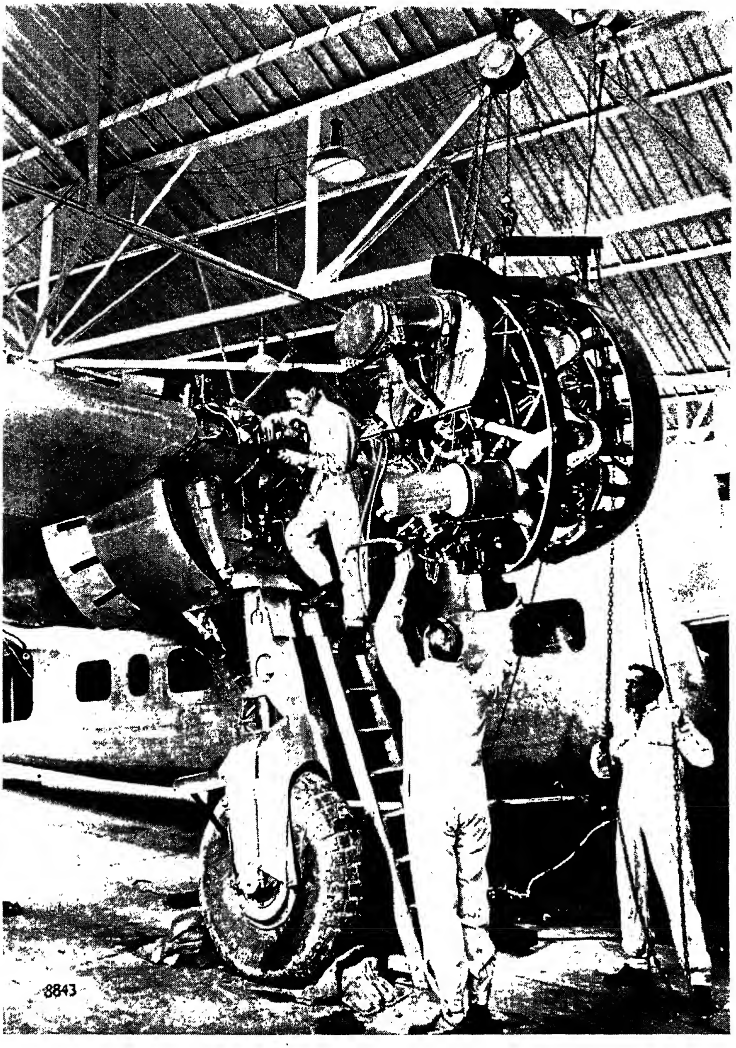

Fig. 11.—INSTALLATION OF PERSEUS ENGINE IN DE HAVILLAND "FLAMINGO"

PARTICULARS OF THE BRISTOL SLEEVE-VALVE ENGINES

Engine Type	*Maximum Take-off Power B.H.P.*	*International Rated Power B.H.P.*	*Max. Power for All-out Level Flight (5 mins.) B.H.P.*	*Cubic Capacity*	*Overall Diameter*	*Airscrew Reduction Gear Ratio*
"HERCULES II" Medium Supercharged	1,290	1,100/1,150 at 5,000 ft. (1,520 m.)	1,375 at 4,000 ft. (1,220 m.)	2,360 cu. in. (38·7 litres)	52·0 in. (1·32 m.)	0·444
"TAURUS" Medium Supercharged	1,010	860/900 at 5,000 ft. (1,520 m.)	1,065 at 5,000 ft. (1,520 m.)	1,550 cu. in. (25·4 litres)	46·25 in. (1·175 m.)	0·444
"PERSEUS X" Fully Supercharged	750	700/730 at 14,500 ft. (4,420 m.)	880 at 15,500 ft. (4,730 m.)	1,520 cu. in. (24·9 litres)	52·0 in. (1·32 m.)	0·500
"PERSEUS XI & XII" Medium Supercharged	830	715/745 at 6,500 ft. (1,980 m.)	905 at 6,500 ft. (1,980 m.)	1,520 cu. in. (24·9 litres)	52·0 in. (1·32 m.)	XI : 0·572 XII : 0·500
"PERSEUS XIIc"	890	680/710 at 4,000 ft. (1,220 m.)	815 at 6,000 ft. (1,830 m.)	1,520 cu. in. (24·9 litres)	52·0 in. (1·32 m.)	0·500
"AQUILA IV" Civil Rated	600	450/470 at 4,500 ft. (1,370 m.)	540 at 6,000 ft. (1,830 m.)	950 cu. in. (15·6 litres)	46·0 in. (1·168 m.)	0·500

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The engine is first of all motored for about quarter of an hour by an electric motor, and then allowed to run under its own power at low r.p.m. for some time while any necessary adjustments are made to the carburetter.

The engine is then put through the endurance test, and after the various readings and power checks have been passed it is returned to the shops where it is stripped down for a careful inspection. Following this the engine is re-erected and again sent to the test stand for the final test of power, slow-running and acceleration. Having successfully passed the final test the engine returns to the shops for an external inspection, and is then prepared for despatch.

If the engine is a new type or embodies some particular modifications it might undergo a considerable amount of flight testing, but the normal production engine would be ready for installation in a production airframe.

Standardised Power Unit

The variety of power units and equipment has emphasised the necessity for standardising the installation of engines and their accessories, and in this respect considerable development has been carried out with the sleeve valve engine, so that the unit may be established on a production basis.

A typical power unit is shown in Fig. 8. It comprises a two-row Hercules sleeve valve engine with airscrew, exhaust system, cowling and controllable cowl gills, accessories, and auxiliary drive gearbox mounted on the bulkhead. It will be seen that the engine unit is carried in a triangular tubular mounting for attaching to four standardised pick-up points in the front bay of an airframe.

The various electrical, mechanical and hydraulic connections are grouped at the bulkhead so that interchangeability between aircraft may be obtained.

Installation

The Perseus engine with its flat-topped cylinder head allows a close-fitting ring cowl to be fitted which is a useful feature when control of cooling air is so important. An installation diagram of the Perseus is shown in Fig. 9, and in Figs. 10 and 11 are seen particulars of the engine in the De Havilland air liner "Flamingo."

BOMBER.

Fig. 3.—Diagram showing how the airframe is split into simple elements in the Handley Page "split component system" of production.

FUSELAGE

The all-metal fuselage is a duralumin monocoque built in three sections to facilitate manufacture, repair and transport. The covering of the entire fuselage is alclad aluminium sheet mounted on hoop frames and longitudinal members. The front and rear sections of the fuselage provide accommodation for the personnel and equipment and the tail boom of oval section connects the rear section of the fuselage to the tail unit. The flooring is built of aluminium members covered with three-ply ash.

Central Cabin

The central cabin of the aeroplane forms an enclosed flying gun platform, with the crew enclosed in special cockpits, at the same time affording the front and rear gun stations clear fields of fire.

Fig. 4.—THE OUTER WING.

Pilot's Cockpit

The pilot's cockpit is located immediately behind and above the bomb aimer's station. It is of the totally enclosed type and provides a good all-round view. The fixed gun is easily operated by the pilot, and is clear of the flying controls.

Bomb Aimer's Station

The duties of bomber, front gunner and navigator are performed at this station, from which an exceptionally clear field of view can be obtained.

Top Gunner's Station

The top gunner's station is located aft of the main spar bulkhead, above the lower rear gunner. The member of the crew seated here normally acts as wireless operator, and faces aft with an uninterrupted field of view over the tail of the aeroplane.

Rear Lower Gunner's Station

The rear lower gunner's station is situated in a balcony turret at the aft end of the deep section fuselage, completely screened from the air stream, and provides a clear field of fire under the tail.

Parachute Exits

Parachute exits are provided for each member of the crew.

EQUIPMENT

Wireless

Wireless is installed in the rear part of the top rear gunner's station and can be used from the same seat.

Automatic Pilot

The aeroplane is designed to take an automatic pilot, if required.

Automatic Camera

An automatic camera is fitted in the space immediately below the wireless set.

WING CONSTRUCTION

Main Planes

The three sections of the wing, port, centre and starboard, are of a similar construction. The spar of each plane consists of a main beam forward of which are fitted tubular ribs carrying an alclad sheet nose covering and a "false spar beam," the whole forming a torsionally stiff member of "D" section.

Fig. 6.—Wing nose covering removed exposing engine controls, hydraulic pipe lines, electric wiring, etc.

Wing Tips

The wing tips are easily detachable, which permits of rapid repair in case of damage, as well as facilitating inspection of the interior of the wings.

Centre Section

In the case of the centre section of the aeroplane the alclad sheet nose covering is readily detached from the "false spar beam" to allow of ease of inspection and maintenance of engine controls, hydraulic pipe lines and electric wiring, all of which are located along the face of the spar beam.

"D" Section—Aft

Aft of the "D" section of both outer and centre section wings, the wing section is completed by an alclad skin riveted to ribs of drawn section closed channel and tubular bracing, except at the engine bays where the forward portion of the ribs aft of the "D" spar are of plate construction.

CONTROL SURFACES AND CONTROL SYSTEMS

High Lift Device

In order to obtain a wide variation of speed range and gliding angle with complete safety, and to permit heavily loaded aircraft to operate from small aerodromes, it is becoming universal practice to provide some device to give improved wing characteristics for these conditions. A combination of Handley Page leading edge slot and rear trailing edge slotted flap is therefore used on the "Hampden," which has proved highly successful in these all-metal aircraft, and which permits a greatly reduced take-off run and allows landings to be performed at slow speed. Due to the presence of front slots the aircraft can be flown with complete safety at the lowest possible flying speed.

Tail Plane and Elevators

The all-metal tail plane is of the fixed cantilever type. As in the case of the wing panels and centre section, the nose portion of the tail plane is

Fig. 9.—TAIL UNIT ASSEMBLY.

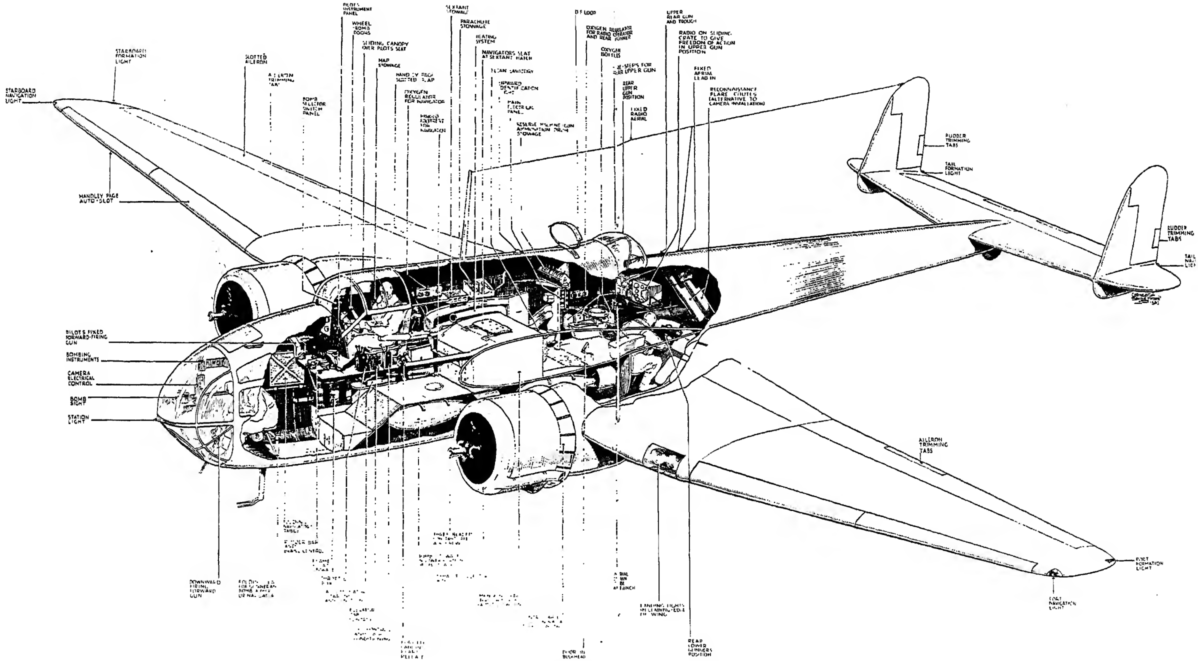

Fig. 10.—DIAGRAMMATIC VIEW OF HANDLEY PAGE HAMPDEN.

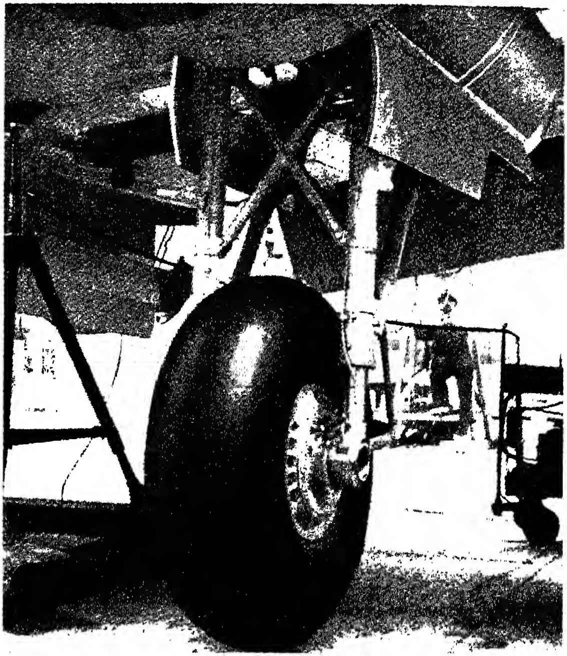

Fig. 11.—RETRACTABLE UNDERCARRIAGE IN DOWN POSITION.

detachable, thereby permitting access to the rudder controls and servo mechanisms which are housed therein. The tail plane tips, as in the case of the main wings, are also detachable. All control mechanisms of both elevators and rudders are completely enclosed.

Twin Fins and Rudders

The twin fins and rudders are of similar construction to the elevator and tail plane, and are mounted on the tail plane.

Flying Controls

A column with segmented control wheel at the top operates the elevator and aileron controls through a bevel wheel drive, torque shaft and pull and push rods. The rudder bar is adjustable and interconnected with the brake gear, and a special arrangement is provided for operating the wheel brakes for parking purposes.

UNDERCARRIAGE AND CHASSIS

Undercarriage

The main undercarriage consists of two units, each of which is retracted into the underside of its respective engine nacelle, underneath which it is situated. The tail wheel retracts into the tail end of the fuselage at the junction of the tail plane. Retraction of this latter component

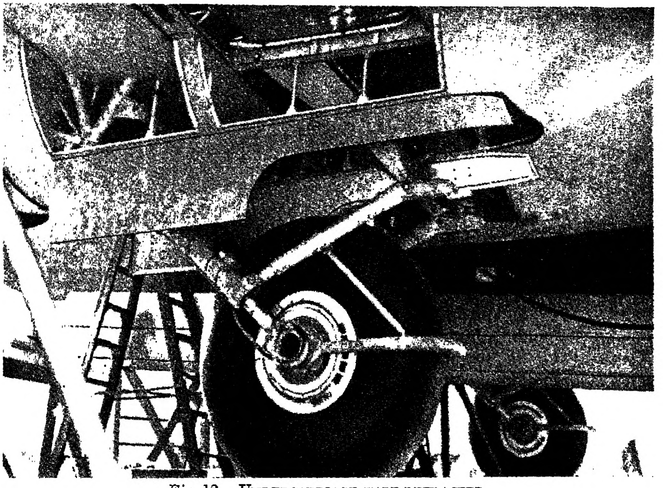

Fig. 12.—UNDERCARRIAGE HALF RETRACTED.

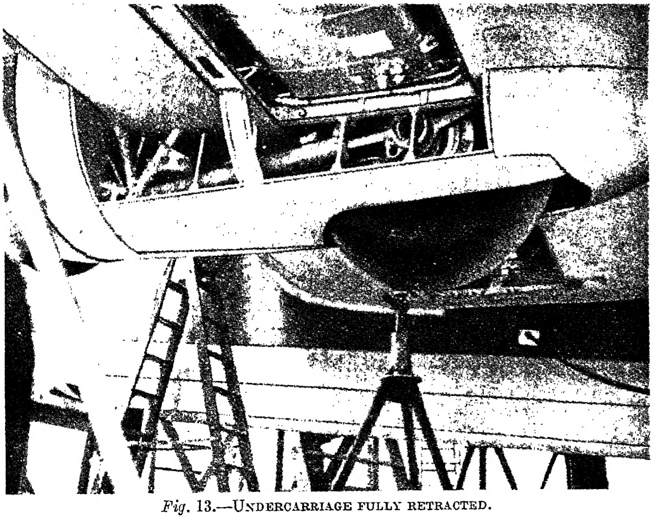

Fig. 13.—UNDERCARRIAGE FULLY RETRACTED.

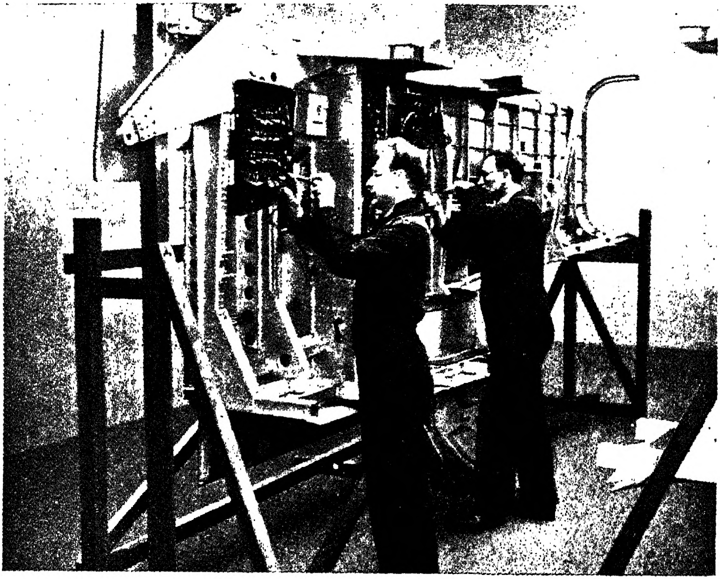

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Fig. 14.—AN EXAMPLE OF THE HANDLEY PAGE SPLIT COMPONENT SYSTEM.

Showing equipment being installed in centre section of fuselage before two halves are united.

takes place simultaneously with the main undercarriage when operated by the pilot through engine-operated hydraulic means. An emergency hand-operating gear is provided, which ensures that the undercarriage can be lowered in the event of mechanical failure.

Wheels and Brakes

The wheels and tyres are of the Palmer type, incorporating pneumatically operated brakes worked by a thumb lever on the control column. Differential action is obtained through the normal movement of the rudder pedals by a similar system.

ENGINE INSTALLATION AND FUEL SUPPLY

The aeroplane is designed to take " Pegasus " XVIII engines, but if need be could be equipped with other engines of the " Pegasus " series. In either case the engines are fitted with N.A.C.A. cowling and controllable

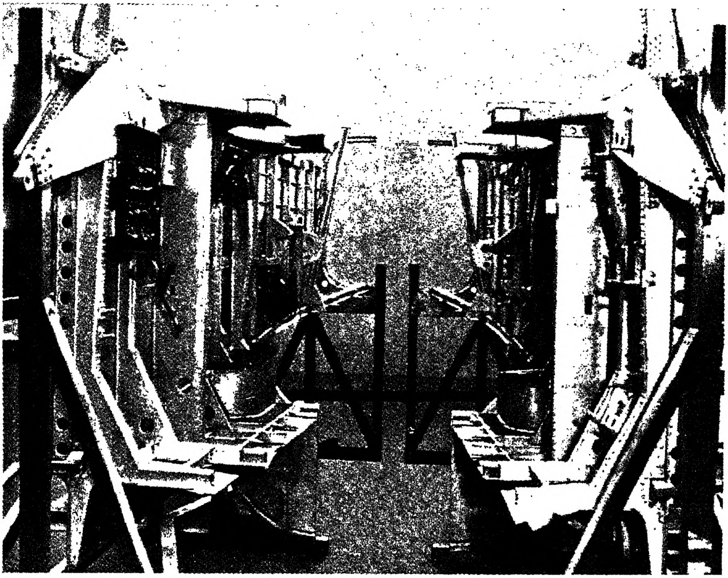

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Fig. 15.—SHOWING EQUIPMENT INSTALLED AND THE TWO HALVES READY FOR JOINING UP.

gills. The mountings are attached to the centre section and consist of welded steel tubular structures triangulated by means of gussetted plates and bolted-on spoke and nipple fastenings. The engines are attached by a flexible mounting to a welded steel ring, which in turn is secured to the engine mounting structure by mushroom-headed bolts.

Changing of Engines

The assembly of the engines to the aircraft is facilitated by the fact that the engine, together with its bearer and all accessory drives, pipe connections, control rods, etc., are built up into one complete unit as far as the bulkhead. The installation in the aeroplane is effected by hoisting the complete unit to four pick-up points on the centre section, at which stage the final engine and fuel connections can be made.

Airscrews

The airscrews used on the " Hampden " are each of the three-bladed de Havilland constant speed type.

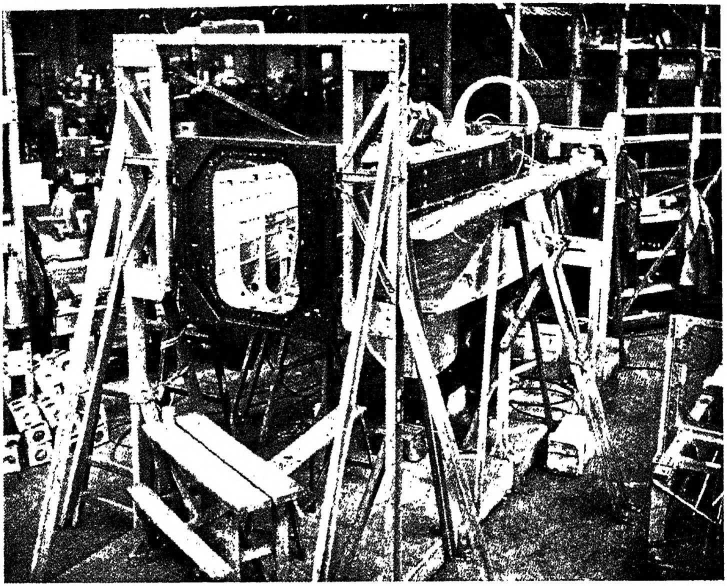

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Fig. 16.—THE JIG IN WHICH THE TWO HALVES OF THE CENTRE SECTION OF THE FUSELAGE ARE UNITED AFTER INSTALLATION OF EQUIPMENT.

Fuel Tanks

The fuel tanks are situated inside the centre section portion of the wing, and the supply for each engine is a complete unit consisting of three aluminium alloy tanks.

In the case of damage by enemy action, or through any other defects, the fuel tanks can be isolated from the rest of the system. The contents of the tanks is indicated by a fuel contents gauge electrically operated and located in the pilot's cockpit.

Engines

Bristol Pegasus XVIII
Napier Dagger VIII
Rolls Royce Merlin X

Fuel

Petrol—maximum .	654 gall.	2,975 litres
Oil—maximum .	36 gall.	164 litres